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THE HOT SPRINGS OF NEW ZEALAND

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BY

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CONSULTING BALNEOLOGIST TO, AND LATE GOVERNMENT BALNEOLOGIST TO,
THE DOMINION OF NEW ZEALAND

WITH THREE MAPS AND EIGHTY-SEVEN ILLUSTRATIONS

LONDON

H. K. LEWIS & CO. LTD.

1921 .

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P R E F A C E

THE object of this book is to bring before the notice of the medical profession the value of the mineral waters of New Zealand.

In New Zealand itself, and to a certain extent in Australia, they are of course well known, and indeed it is probable that in no other country has a larger proportion of the population taken advantage of the presence in its midst of thermal springs.

Thus, although the population of New Zealand is only about a million, there were given, during the seventeen years in which the author was in charge, nearly two and a half million baths at Rotorua alone, although of course a certain proportion of the bathers were visitors from overseas.

The events of the last few years have brought home to all of us the necessity for making the British Empire self-supporting, and it is well that the available resources of that Empire should be made known as widely as possible amongst its members.

It is with no thought of belittling the springs and spas of the British Isles that the merits of those so far afield are thus brought forward.

No one more than the author, who himself practised for several years at an English spa, is more fully impressed with their value, but all of us must also admit their limitations.

The British Isles are deficient in certain waters, and for that reason great crowds of patients every year flocked to foreign spas. Many of these spas are now, and perhaps will be for many years to come, practically closed to British

visitors, and it behoves us to see whether within the confines of our own dominions we cannot fill the deficiency.

With the exception of purgative waters, the missing springs can certainly be supplied in New Zealand, and there are certain waters, such as the nascent sulphuric acid waters at Rotorua, which are of a potency and therapeutic value undreamed of in England, and which are wholly unrepresented in Europe.

The author, in pressing the merits of the New Zealand spas, makes no claim that they can compete on what may be termed social lines with those of the Old World. In the matter of theatres, music, indoor amusements, and so forth, they are woefully deficient; but in his opinion, what they lack in this direction is more than counterbalanced by their other attractions.

Change of environment is one of the most potent weapons in our armamentarium; and the change of scene from, say, an English town to the Thermal District of New Zealand with all its wealth of weird and wonderful sights, its beautiful lakes, rivers, mountains, and forests, its geysers, boiling springs, and mud volcanoes, its Maori villages with their picturesque inhabitants, the cottages crazily and precariously perched on the brink of boiling destruction, the housewife washing clothes in a hot spring, or nonchalantly cooking the dinner in a steam-hole—all these things provide more change of scene than a mere trip to a cosmopolitan Continental spa.

For such shortcomings as the New Zealand spas may possess—and they are of course as numerous as elsewhere—the author must bear, at any rate in part, the blame. He was appointed in 1902 as Government Balneologist to advise in the development of the health resorts of New Zealand. Such a unique appointment carries with it corresponding responsibilities, and the author is keenly aware of his deficiencies. The wealth of material was so great, the choice so large, that it was a matter of extreme difficulty to choose a policy. Rightly or wrongly, the line he advised was

to develop one spa, Rotorua, thoroughly, rather than attempt, with limited means, to develop half a hundred; and so the visitor may rest assured that at Rotorua, at any rate, he will find the balneological amenities to which he is accustomed nearer home.

Further, he will find, if he be so minded, an unwonted charm in the simplicity and naturalness of the lesser spas; and if he be so unconventional as to venture to leave the tourist beaten track, and philosophic enough to put up with a few minor discomforts, his venturesomeness will not go unrewarded. Some of the author's pleasantest recollections are of long excursions into the "back country," of a tent pitched before sunset and bedded with fern, and of a bath in a spring or a hot bubbling river under the stars, while the "billy" boiled for the evening meal.

There comes to all of us, unhappily, a time in which the illusions of youth are lost. The author labours under no illusions that a book such as this will be read through from beginning to end, save by the heroic few. The busy practitioner has so many and diverse calls, intellectual and physical, on his time, that it is contrary to all our experience of human nature to expect him to delve deeply into the intricacies of a subject in which he may be only remotely concerned, and he may well feel inclined to skip such chapters as those dealing with the principles underlying balneological treatment.

Should he, however, desire fuller information, and have no standard work on balneology at hand, these pages have been inserted, not without some diffidence, for his guidance.

In the tabulated analyses of mineral waters the results are compiled from the figures published by the Dominion Analyst, and are expressed as salts in grains per gallon. According to modern views this is not a strictly scientific method of expression, as it is now generally assumed that the various substances present in mineral water exist, in part at any rate, in the form of dissociated ions and not of actual salts.

A result expressed in terms of ions is, however, unintelligible to any but the expert chemist, and would be of no practical guidance to the doctor—and practical utility is essentially the aim of this work.

Too much stress, however, should not be laid on the mere chemical composition of a water. The majority of the so-called rheumatic and allied diseases are now known to be toxæmias of bacterial origin, and a mineral water is used even more often for its physio-therapeutic than for its pharmacological properties. Balneology, in fact, marches hand in hand with bacteriology, and it would even appear as if, in the near future, in the treatment of many chronic diseases it will be regarded as an adjunct, though an invaluable adjunct, of that branch of science.

With the exception of the tables of analyses, however, the remainder of the work is original, and represents the author's personal experience and views, and, as an excursion into hitherto untrodden country, is published with the hope that it may be interesting as well as useful.

The first few chapters have been inserted largely for the benefit of the patient himself.

There can be very few intelligent visitors to the Thermal District who do not burn with curiosity to understand something of the why and wherefore of the wonderful thermal phenomena they see around them; and so a brief, and, it is trusted, a comprehensible, account is given of the geological factors involved in the evolution of geysers, volcanoes, and other "sights."

Finally, the author acknowledges gratefully the kindness of the Government Meteorologist in contributing a chapter on the climate of New Zealand.

ARTHUR S. HERBERT.

I UPPER PHILLIMORE PLACE,
KENSINGTON, W.
March 1921.

CONTENTS

PART I

DESCRIPTIVE

| CHAPTER | PAGE |
|---|------|
| I. ROUTES AND GENERAL DESCRIPTION | 3 |
| II. HYDROTHERMAL PHENOMENA | 15 |
| III. HOT SPRINGS | 24 |
| IV. GEYSERS AND BOILING MUD SPRINGS | 33 |

PART II

BALNEOLOGICAL

| | |
|--|-----|
| V. THE MINERAL-WATER HEALTH RESORTS—SPAS | 51 |
| VI. THE SULPHUR SPAS | 54 |
| VII. THE ALKALINE SPAS | III |
| VIII. THE SALINE SPAS | 123 |
| IX. THE CALCIUM SPAS | 130 |
| X. THE SIMPLE THERMAL SPAS | 134 |
| XI. CLASSIFICATION OF THE RHEUMATIC DISEASES | 137 |
| XII. SPAS SUITABLE FOR INDIVIDUAL CASES | 144 |
| XIII. CLASSIFICATION AND ANALYSES OF THE MINERAL WATERS | 162 |
| XIV. THE CLIMATE OF NEW ZEALAND | 211 |

PART III

BALNEOLOGICAL PRINCIPLES

| CHAPTER | PAGE |
|---|------|
| XV. SPA TREATMENT | 225 |
| XVI. MINERAL-WATER TREATMENT | 229 |
| XVII. ACCESSORY PHYSICAL TREATMENT | 257 |
| XVIII. DIET | 268 |
| XIX. ENVIRONMENT—CLIMATE—SUGGESTION | 274 |
| APPENDIX | 276 |
| INDEX | 277 |

LIST OF ILLUSTRATIONS

FIG.

| | |
|--|-----------------------|
| I. WAIROA GEYSER, WHAKAREWAREWA, ROTORUA | <i>facing page</i> 3 |
| 2. MAP SHOWING NEW ZEALAND IF PLACED IN CORRESPOND- ING LATITUDE OF NORTHERN HEMISPHERE . . . | page 5 |
| 3. MAP OF NORTH ISLAND, SHOWING THERMAL DISTRICT . . . | ,, 9 |
| 3A. MAP OF THERMAL DISTRICT | 13 |
| 4. DIAGRAMMATIC SECTION OF A VOLCANO | ,, 19 |
| 5. WAIMANGU IN ERUPTION | <i>facing page</i> 20 |
| 6. WAIMANGU IN ERUPTION | ,, 21 |
| 7. DIAGRAM OF THE FORMATION OF ACID MINERAL WATER | <i>page</i> 30 |
| 8. A SMALL GEYSER, WHAKAREWAREWA | <i>facing page</i> 33 |
| 9, A. FUMAROLE ON SLOPING SURFACE | <i>page</i> 34 |
| 9, B. FUMAROLE ON A CLIFF-FACE | ,, 35 |
| 9, C. FUMAROLE ON GENTLY SLOPING SURFACE | ,, 36 |
| 9, D. FUMAROLE ON HORIZONTAL SURFACE | ,, 37 |
| 10. DIAGRAM OF THE GREAT GEYSER OF ICELAND | , 38 |
| 11. PAKAKURA GEYSER | <i>facing page</i> 38 |
| 12. A CLOSE VIEW OF THE MOUTH OF PAKAKURA GEYSER | <i>facing page</i> 38 |
| 13. A GEYSER OPENING THROUGH A POOL OF BOILING WATER | <i>facing page</i> 38 |
| 14. ANOTHER VIEW OF THE SAME GEYSER | ,, ,, 38 |
| 15. THE MOUTH OF AN EXTINCT GEYSER | ,, ,, 38 |

FIG.

| | |
|---|-----------------------|
| 16. THE "BRAIN-POT," WHAKAREWAREWA | <i>facing page</i> 38 |
| 17. DIAGRAM OF GEYSER | <i>page</i> 40 |
| 18. DRY-MOUTHED GEYSER | 42 |
| 19. BOILING SPRING ON BANKS OF WAIKATO RIVER | 43 |
| 20. DIAGRAMMATIC SECTION OF CONE OF GEYSER | 44 |
| 21. A "CHAMPAGNE POOL" | <i>facing page</i> 44 |
| 22. THE Malfroy Geysers, Rotorua | 44 |
| 23. Wairoa Geyser, Whakarewarewa | 44 |
| 24. CONE OF WAIKITE GEYSER | 44 |
| 25. A SILICA TERRACE | 44 |
| 26. SILICATED TWIGS AND LEAVES | 45 |
| 27. FLOOR OF A SILICEOUS POOL | <i>page</i> 45 |
| 28. MUD VOLCANO IN ACTIVE ERUPTION | 46 |
| 29. A BOILING MUD POOL | <i>facing page</i> 48 |
| 30. A BOILING MUD POOL | 48 |
| 31. SURFACE OF A "PORRIDGE-POT" | 48 |
| 32. "THE INFERNO," TIKITERE | 48 |
| 33. CONES OF MINIATURE MUD VOLCANOES | 48 |
| 34. A STUDY OF MINIATURE MUD-VOLCANO CONES | 48 |
| 35. THE SAME CONE AS IN FIG. 28, IN A QUIESCENT STAGE | <i>facing page</i> 48 |
| 36. HINEMOA'S BATH | 52 |
| 37. A GIANT AZALEA | 61 |
| 38. FLY-FISHING AT OKERE | 61 |
| 39. WAR CANOE | <i>page</i> 61 |
| 40. THE MAIN BATHS, ROTORUA | <i>facing page</i> 62 |

| | |
|---|-----------------------|
| FIG. | |
| 41. THE BATHS, ROTORUA | <i>facing page</i> 62 |
| 42. OHINEMUTU | 64 |
| 43. MAORI WOMAN COOKING IN A STEAM-HOLE | 64 |
| 44. A NATURAL KITCHEN RANGE | 64 |
| 45. A HOT "LAKE," OHINEMUTU | 64 |
| 46. A MAORI MOTHER AND CHILD | 64 |
| 47. A MAORI LAUNDRY | 64 |
| 48. WEAVING A FLAX MAT | 64 |
| 49. HONGI, A MAORI GREETING | 64 |
| 50. A POI DANCE | 64 |
| 51. A FIGURE OF THE POI DANCE | 64 |
| 52. ANOTHER FIGURE OF THE POI DANCE | 64 |
| 53. A HAKA | 64 |
| 54. A FIGURE IN THE HAKA | 64 |
| 55. ANOTHER FIGURE IN THE HAKA | 64 |
| 56. EXAMPLE OF MAORI WOOD-CARVING | 64 |
| 57. PANORAMA OF HANMER PLAINS. | 93 |
| 58. A BATH-HOUSE, HANMER | 96 |
| 59. QUEEN MARY'S HOSPITAL, HANMER | 96 |
| 60. MUD VOLCANO, WAI-O-TAPU | 100 |
| 61. THE "DEVIL'S BRIDGE," WAI-O-TAPU | 100 |
| 62. THE "ECHO LAKE," WAI-O-TAPU | 100 |
| 63. NATURAL WARM SWIMMING-BATH, WAIRAKEI | 103 |
| 64. THE WARM SWIMMING-BATH, WAIRAKEI | 103 |
| 65. THE "GREAT GEYSER," WAIRAKEI | 103 |
| 66. THE "DRAGON'S MOUTH" GEYSER, WAIRAKEI | 103 |

FIG.

| | | |
|---|---------------|-----|
| 67. OUTFLOW FROM THE GREAT GEYSER | . facing page | 103 |
| 68. KERAPITI BLOW-HOLE | „ „ | 103 |
| 69. THE HUKA FALLS | „ „ | 103 |
| 70. ARATIATIA RAPIDS | „ | 103 |
| 71. THE " TWINS " GEYSER, WAIRAKEI | page | 104 |
| 72. MOUTH OF THE " TWINS " GEYSER | „ | 105 |
| 73. " EAGLE'S NEST " GEYSER, WAIRAKEI | „ | 106 |
| 74. " CROW'S NEST " GEYSER, TAUPO | . facing page | 106 |
| 75. A BOILING SPRING, TAUPO | „ „ | 107 |
| 76. THE DINING-HALL, THE SPA, TAUPO | page | 107 |
| 77. THE BATHS, TE AROHA | . facing page | 111 |
| 78. THE BOWLING GREEN, TE AROHA | „ | 112 |
| 79. A GROVE OF NIKAU PALM AT MORERE | „ „ | 126 |
| 80. THE BATH-HOUSE, MORERE | page | 127 |
| 81. LIMESTONE ROCKS, KAMO | . facing page | 130 |
| 82. THE HANDS IN RHEUMATOID ARTHRITIS | „ „ | 140 |
| 83. X-RAY OF HAND IN RHEUMATOID ARTHRITIS „ „ | „ „ | 140 |
| 84. SPUR FROM THE OS CALCIS | „ „ | 140 |
| 85. DIAGRAM OF X-RAY PICTURES | „ „ | 141 |
| 86. TOPIACEOUS MASSES IN THE HAND OF A MAORI | page | 146 |

PART I
DESCRIPTIVE



FIG. 1.—WAIROA GEYSER, WHAKAREWAREWA, ROTORUA.

CHAPTER I

ROUTES AND GENERAL DESCRIPTION

Comparison with the British Isles.—New Zealand has been termed the “ Britain of the South.” The description for once in a way is really apt, for while, as a general rule, one is prone, and justly prone, to mistrust the facile labels which are nowadays so freely distributed, in this case the name is fully justified.

Of course, in dealing with the southern hemisphere, there is a necessary inversion of northern ideas and terms; the South is cold and the North is hot, and Christmas falls at midsummer. Allowing, however, for this inversion, it is curious how closely parallel are these two Britains of the North and South.

Lying in the Southern Ocean, almost exactly antipodean to Britain, New Zealand also consists of two main islands, though in this case they lie end to end and north and south, instead of side by side and east and west.

The Scotch mountains of the north are represented, and eclipsed, by the Southern Alps; the lochs of the western highlands have their counterpart, though on a grander scale, in the fiords and sounds of the South Island; and the southern extremity of the country is very largely Scotch. The cold north-east wind of Britain is, for much of New Zealand, represented by the south-west, and the north-east wind brings rain and warmth.

It is of course easy to pursue analogy farther than is profitable. Every country and every community has special individualities which mark it out as a thing apart, and without such characteristics the world would be robbed

of half its charm. It is the pride of New Zealand that, while she is, of all the daughter nations, the one most nearly like the mother country, she is yet most unmistakably stamped with her own individuality, is a young, vigorous, and original nation and no mere copy.

Climate.¹—Although lying much nearer to the equator, roughly between lat. 34° and 47° S., than do the British Isles, which lie between lat. 50° and 59° N., the climate of the two countries is by no means so dissimilar as these figures would indicate. For while Britain is warmed by the Gulf Stream, New Zealand is kept more temperate by the enormous surrounding areas of the southern oceans. Thus New Zealand corresponds in latitude to Italy in the northern hemisphere (vide fig. 2); but to get an approximately equal climate, one would have to imagine Italy an island shifted, say, five hundred miles north-west of the coast of Portugal. As compared with the British Isles there is in New Zealand more sunshine, and warmer sunshine; less mist and fog, and fewer grey days; a slightly heavier rainfall, with fewer rainy days; perhaps, if anything, rather more wind. There is, however, much less contrast between summer and winter. The summer climate of New Zealand is somewhat warmer, and in this there is much less difference between the North and South Islands than might be anticipated, while the winter climate is, except on the inland highlands of the South Island, distinctly milder than that of the south of England. In a word, the climate is more equable, more sunny, and somewhat warmer.

It is the climate of England at its best, "only a little more so."

The contrast of the changing seasons is also minimized by the character of the vegetation. With few exceptions the native trees and shrubs are evergreen, and it is only in those increasing areas planted with deciduous European

¹ For a fuller and more technical account of the climate the reader is referred to pages 211-221, which have been kindly contributed by the Government Meteorologist, the Rev. D. L. Bates.

trees that the bare boughs bring home to one the fact of winter.

In the matter of elevation the principal spas are fortunately placed, and allow a good deal of choice. Thus, in the North Island, Te Aroha, Waiwera, Helensville, and several others are at or near the sea-level; the "thermal district," including Rotorua, Wairakei, and Taupo, is on an elevated inland plateau a thousand feet or so above sea-level; Hanmer, in the South Island, is somewhat higher, and in bracing mountainous country.

As purely mountainous resorts there are "The Hermitage" at Mount Cook, at an altitude of 2,500 feet, with easy access to mountain huts higher up, and an accommodation house high up on Mount Egmont, near New Plymouth.

Bracing resorts at medium altitude are Queenstown, on Lake Wakatipu, and the small towns on the upland plateau of Central Otago.

Ocean Routes.—It must be confessed that New Zealand lies "a long way from anywhere." From Australia it means about four days' passage from Sydney to Auckland or from Melbourne to Wellington, while from England it means a minimum of from four to six weeks, whatever route be taken.

While, however, this great distance presents many drawbacks, especially to the tourist with limited time at his disposal, to the invalid not too hampered by such considerations the long voyage is, in many cases, a distinct advantage.

Thus in cases of chronic disease—and it is of course for chronic diseases that spa treatment is especially indicated—the prolonged enforced rest, the abundant fresh air and sunshine, and the novel surroundings of an ocean voyage are very material aids to recuperation, and form an excellent preliminary to a course at a spa and an equally excellent "after cure."

There is also considerable choice of routes, so that a traveller need not be bored by retracing his steps on his homeward journey. Again, a route can be chosen to suit

the special needs of an invalid. Thus, if it be desirable that he should get plenty of change of scene and interest, he should be sent via the Mediterranean, calling at French and Italian ports, the Suez Canal, Colombo, and Australia. In Australia he will probably get a day or two at Perth, Adelaide, and Melbourne, before disembarking at Sydney for Auckland. He can return by an alternative route via Vancouver and across Canada, or by the Panama Canal. Should the Suez route be chosen, care should be taken, in the case of delicate patients, to avoid the summer months in the Red Sea ; but as, under ordinary conditions, he would be leaving England in autumn to catch the New Zealand summer, any excessive heat is not likely to be encountered there, and it is not until he gets to Ceylon that he encounters much in the way of tropical conditions. Australia will, of course, be reached in the early summer, but if he times his journey to arrive about November he will probably find the climate delightful.

Should, on the other hand, it be desirable to rest the patient as much as possible, to avoid the fatigue and excitements of landing at ports, and to avoid prolonged heat, he should be sent via the Cape. By this route he will probably touch at Teneriffe, Cape Town, and Hobart, and on his return journey can go round Cape Horn, only calling at a South American port ; and the passage through the tropics, both in going out and coming home, will be comparatively short.

The choice of routes will depend, then, partly on climatic requirements and partly on the idiosyncrasy of the patient. If he is liable to be bored by the monotony of a long sea voyage and few ports, he had better avoid the Cape route, and perhaps Panama.

Clothing.—The invalid, by leaving England in the autumn, will be getting *three summers running*, and he will necessarily spend several weeks under tropical conditions. A tropical outfit for board-ship will therefore certainly be needed, but he will be well advised to wear very thin white flannel

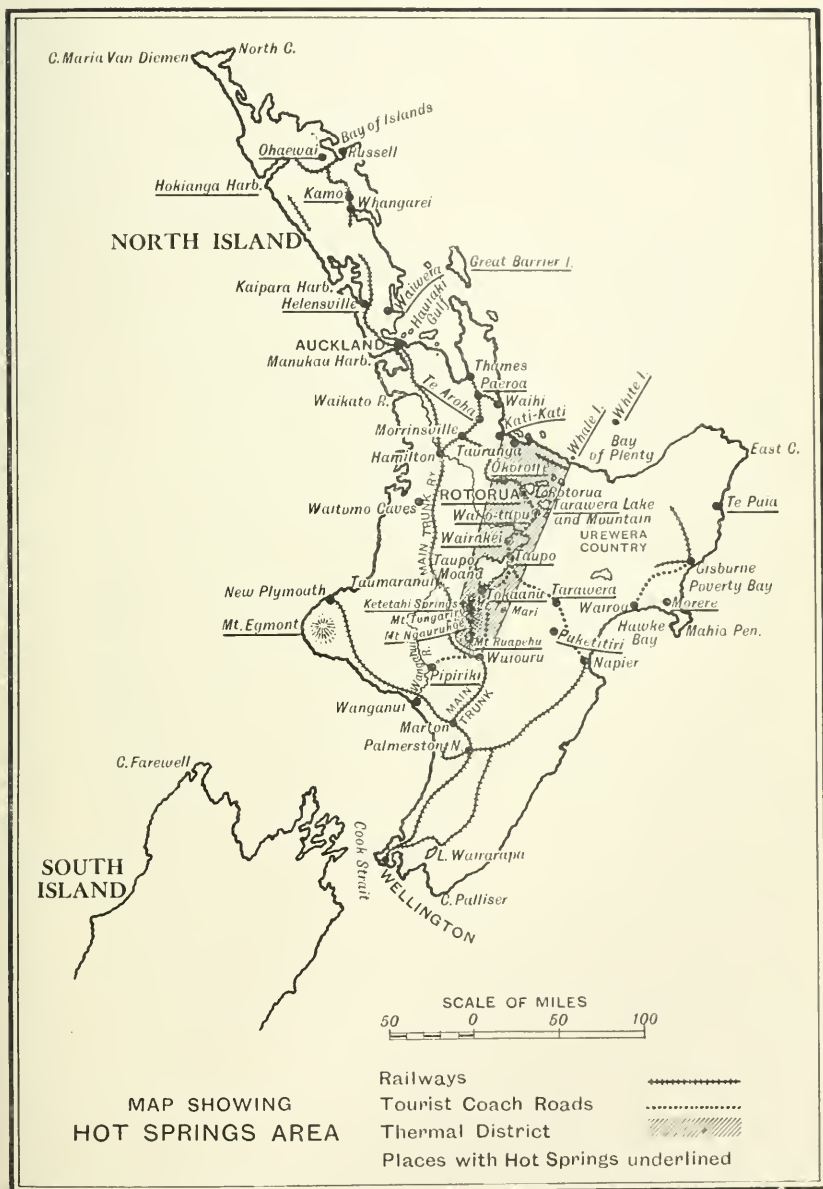


FIG. 3.—MAP OF NORTH ISLAND, SHOWING THERMAL DISTRICT AND MAIN HOT SPRINGS CENTRES.

rather than white duck. In New Zealand he will find that what suited him for an English summer will suit him for a New Zealand one. Visitors from Australia need hardly be reminded how much cooler the New Zealand summer is than their own.

Access on Landing.—A glance at the accompanying map (fig. 3) will show that the spas of New Zealand are, with the exception of Hanmer, confined to the North Island. While there are numerous places marked as mineral springs, and still more numerous springs unnamed, the average overseas invalid will probably be making either for Rotorua or Te Aroha, while the tourist will surely find himself sooner or later in the Thermal District.

In the vast majority of cases travellers will be disembarked at either Auckland or Wellington. The journey from Auckland to Rotorua is only 170 miles by train, while from Wellington it means a long and tedious journey. There is, however, a sleeping-car on the train. Te Aroha is reached by a branch from the Rotorua line.

Thermal District.—The thermal district covers a very extensive area (vide map 3A). Its limits are of course somewhat difficult to define, and indeed there are large numbers of hot springs far outside its uttermost boundaries, but as a matter of convenience it is held to include the zone of volcanic springs ranging from the central volcanoes south of Taupo in a northerly and north-easterly direction to White Island and Whale Island in the Bay of Plenty. The main geographical features of this district are that it is an elevated pumice plateau, 1,000 to 1,500 feet above sea-level, dotted with numerous large lakes and with isolated extinct volcanic cones, and culminating in the very centre of the North Island in a group of active, extinct, and semi-extinct volcanoes. Of these mountains, snow-clad Ruapehu (9,175 feet), a volcano extinct but for its hot springs, is the highest point in the island and dominates its sister mountains Ngauruhoe (7,515 feet), a still active volcano, and Tongariro (6,400 feet).

12 THE HOT SPRINGS OF NEW ZEALAND

At their feet lies Taupo Moana,¹ a lake some twenty miles or more in length and nearly as much in breadth. This lake, largely fed by the melting snows of the mountains, overflows by the great Waikato River to the sea, and on its shores, at Tokaanu and Taupo, and on those of the upper reaches of the river and its tributaries, as at Wairakei, Wai-o-tapu, and Orakei Korako, may be found innumerable boiling springs, fumaroles, mud volcanoes, and other evidences of hydrothermal activity.

Towards the northern edge of the plateau, and beyond the watershed of the Waikato, will be noticed a chain of numerous lakes, Rotorua,² Roto-iti, Roto-ehu, Roto-ma, Tarawera, Roto-mahana, and many others, grouped around numerous extinct volcanic peaks, while the two last named are at the foot of Tarawera Mountain, which, while now quiescent, was in active eruption in 1886.

Here we find, in addition to numerous isolated springs, two main groups of hot springs, one centred at Rotorua and the other at Rotomahana, and reaching its climax there at the great Waimangu geyser.

The whole of this district is the happy hunting-ground of tourists in quest of wondrous thermal "sights" and of sport, or of invalids in search of health. For both, the centre of the district is Rotorua, for here the railway ends, and here are, besides geysers and hydrothermal sights, baths and all the resources of a modern spa. From here starts the main line of tourist traffic to Waimangu, Wai-o-tapu, Wairakei, and Taupo, and the overland route thence to the Wanganui River on the main trunk line.

¹ Moana—the sea, ocean,—pron. mō-áhna.

² Rōto—lake.

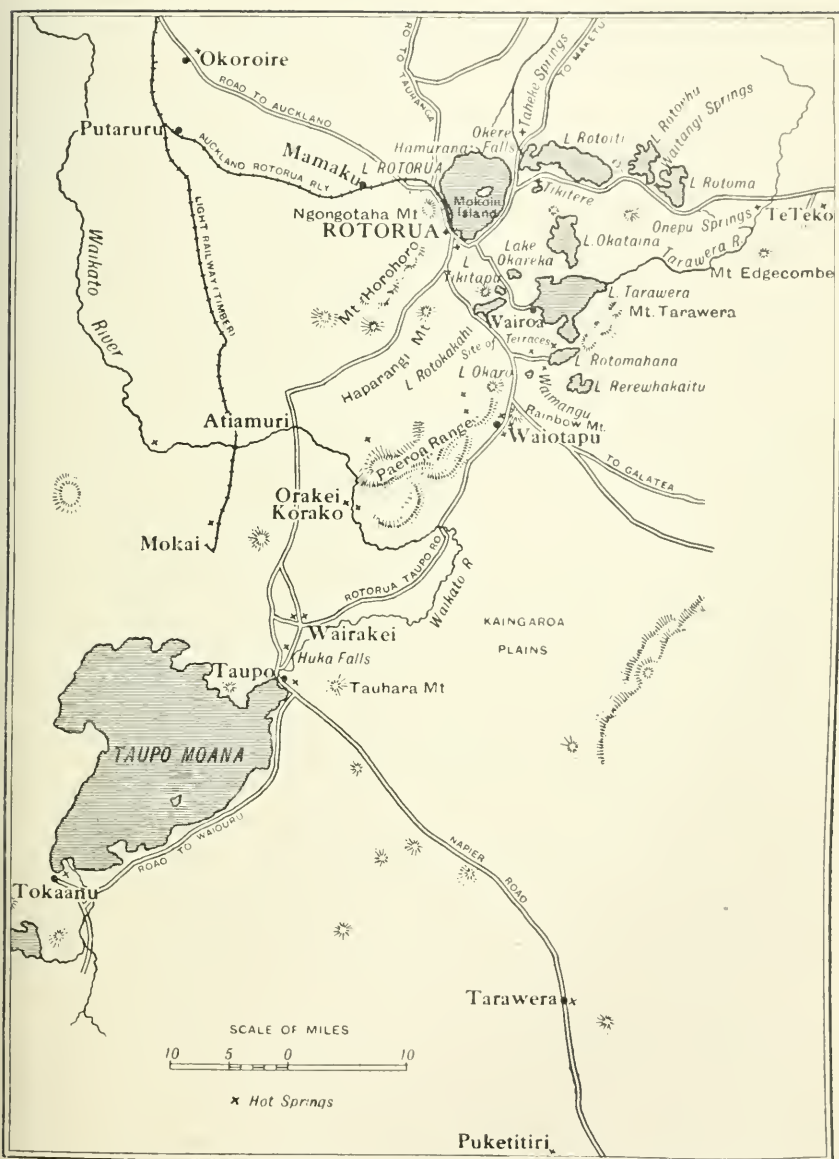


FIG. 3A.—MAP OF THERMAL DISTRICT, SHOWING MAIN TOURIST ROUTES.

CHAPTER II

HYDROTHERMAL PHENOMENA

No one visiting the "Thermal District" of New Zealand can fail to be impressed by the magnitude and variety of the hydrothermal phenomena. On every side one sees hot springs of every size, shape, temperature, and colour. Here a spring is blue and boiling furiously, there a comparatively placid pool may be bright green or perchance a mustard yellow.

Closer investigation will show as great variations of chemical composition, not only in waters of obviously different appearance, but in waters apparently identical. The most casual tourist is interested in the question—"why?" much more so the invalid, who is looking to these same waters to rid him of his malady; and it is felt that a chapter dealing with these phenomena, and, as far as possible, explaining them, can hardly fail to be of general interest.

There are certain phases of the question which can only be explained tentatively, and certain subtle differences of working and appearance which we can hardly explain at all; but on the whole, all the major phenomena can be elucidated on general geological principles, after careful investigation of local conditions.

Fumarole the prototype of all hydrothermal activity.—It will be the purpose of the following pages to attempt to explain how all the protean hydrothermal activities of the district are but children of the parent fumarole or "blow-hole," and that hot springs, geysers, boiling mud springs, silica terraces, and probably even volcanoes, all

have as their primary agent a jet of steam blown out of the earth's hot interior.

To obtain a clear idea of hydrothermal phenomena it is necessary to consider briefly a few elementary facts in geology; and as all the hot springs of the district are of volcanic origin, it will repay us to digress for a time and consider in some detail the structure and *modus operandi* of a volcano. If some of the statements made here may seem somewhat elementary or somewhat dogmatic, it must be remembered that this book is written essentially for the lay reader and not for the geologist.

We must conceive, then, the earth as being composed of a white-hot mass, whose exterior has cooled to a relatively thin, hard crust, and whose interior, the magma, so far from being a molten liquid, is maintained in a solid condition by enormous pressure. It is possible, and even probable, that much of this central mass may consist of superheated gas, but so modified by pressure that it has the physical consistency of a solid.

Somewhere in this hot mass has been heated the water which is the basis of our hot springs and geysers, and which is by most geologists conceived to be the basis of all volcanic action.¹ There are two rival theories as to the origin of this water: it may have come in recent times by percolation from the surface, from leaky river, lake, and ocean beds, and from rain penetrating the soil, or it may have arisen from primeval water imprisoned in the magma through the ages. In the former case it is assumed that it only penetrated the hot crust, that it was heated by

¹ Brun (*Recherches sur l'exhalaison volcanique*) would rather appear to have upset the orthodox theory by his researches. He showed that when "active" unoxidized volcanic rocks are heated to a certain temperature, gas and volatile salts are given off with explosive violence (1 kilo of Krakatoa obsidian yielding 1,577 c.c. of gas at 800° C.), and to this action he attributes volcanic outbursts and the formation of pumice. He points out that water vapour is largely dissipated at 150° C. and wholly so at 300° C. While he asserts that volcanic explosive eruptions are anhydrous, he maintains that solfatara and fumaroles owe their aqueous character to the invasion of partially cooled volcanic rocks by superficial waters.

the rocks and probably never reached the white-hot interior.

It might be thought that the enormous pressure of rising gases and steam would preclude the passage of water beyond a limited depth, but it has been shown pretty conclusively that water can penetrate rocks by capillary attraction against the most enormous forces of heat and pressure.

In favour of this theory of origin is the fact that volcanoes are almost invariably found near the sea or a large lake, and again, in New Zealand at any rate, the hot springs and geysers are almost always close to a river or lake bed, or the sea-shore.

The other theory, that of the primeval "original" water imprisoned in the magma, has at least as many supporters and makes a powerful appeal to the imagination.

According to this theory, before the formation of the earth's crust it was surrounded by a dense atmosphere of steam and gases, the former representing the present waters before their condensation. Much of this steam was absorbed by the molten magma, and has escaped slowly ever since. In what form it is imprisoned is perhaps a matter for conjecture. Under increased pressure of course the boiling-point of water rises, but the process does not go on indefinitely. The critical temperature of water is 773°F. , and as the temperature of the magma near the surface is about $1,500^{\circ}\text{F.}$, and is much more at greater depths, such imprisoned water vapour must be white-hot, and probably exists in a state of "dissociation," and we can only term it indefinitely "water substance." A substance that by reason of pressure and temperature is a white-hot solidified potentially explosive gas is hard to reconcile with our ideas of water!

It is, at any rate, potentially water, though temporarily dissociated into its elements, and, on its reconstitution, it is easy to realize that its solvent and chemical properties may be something vastly different from those of the water with which we are familiar; and it is in some quarters

18 THE HOT SPRINGS OF NEW ZEALAND

suggested that volcanic mineral waters owe part of their efficacy to their origin from " virgin waters " of this type.

As a proof that water is present in abundance in the magma there is the fact that clouds of steam arise from ejected lava, both when fresh and long after its eruption. This is corroborated by the crystalline and vesicular structure of plutonic rocks, caused by imprisoned water, and by the fact that water can be extracted from such rocks when crushed and heated in vacuo. Finally, the unchanging constitution of the mineral waters, arising in such enormous quantities over such great periods of time, would suggest a vast reservoir such as the deep magma rather than a more local and superficial origin.

Whichever theory be correct is a matter for us of academic interest only ; our task is to trace the passage of the steam to the earth's surface.

(1) It may escape as a steam-jet, " blow-hole," or fumarole.

(2) The fumarole may condense below the surface into boiling water and issue as a hot spring or geyser.

(3) Or the fumarole may be on so tremendous a scale that it issues as a volcano.

Owing to shrinkage from cooling and from other causes, the surface of the earth is undergoing folding and crumpling movements ; the lines of folding represent lines of weakness, though it would be exaggeration to call them " cracks." Along these lines the pressure on the underlying mass is lessened, thereby allowing the solid magma to become more fluid, and also reducing the pressure on the water-substance imprisoned in its mass. With explosive force this finds its vent as superheated steam at some weak spot in the crust, with or without the accompaniment of white-hot lava.

Such a vent constitutes a volcano, and a glance at the map of the world shows that the majority of volcanoes tend to form in more or less definite lines near the sea, such as the curved line from the Antarctic through New Zealand, the East Indian Archipelago, and Japan, to Behring

Straits, or that along the west coast of North and South America. Both the linear arrangement of the volcanoes and the margin of the depressed ocean area would appear to be connected with the lines of weakness.

The lava, then, the overflow of magma, is forced up from below, partly by being squeezed out, as we would squeeze paint from a tube, but largely by the explosive force of its imprisoned steam. It is as truly an effervescence then as an open bottle of champagne.

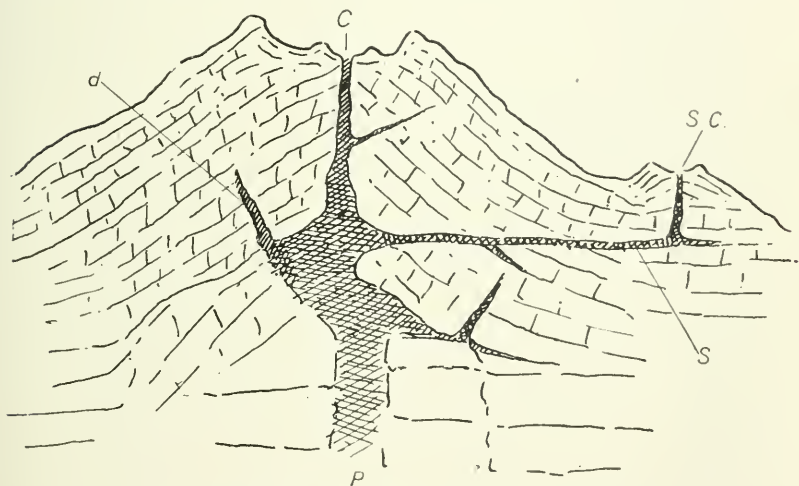


FIG. 4.—DIAGRAMMATIC SECTION OF A VOLCANO.

C. Crater. D. Dyke. P. Pipe. S.C. Secondary Cone. S. Sill.

As it outflows it builds a cone, with a central pipe and a crater, exactly as we see in the Rotorua district mud volcanoes built up by steam forcing its way through clay in hot mud springs and "porridge-pots" (cf. fig. 29, p. 48).

As the volcano rises in height, the lava still brims over its crater lip, and, together with showers of detritus, flows down over its sides, building it yet higher and thicker in a more or less perfect cone. As the cone is built higher, there is an ever-increasing tendency for the tube to get blocked up, and lava may force its way through a weak spot

20 THE HOT SPRINGS OF NEW ZEALAND

in its side and form a secondary cone and crater. Such an event is favoured by the fact that the cone is usually composite in character and arranged in layers (vide fig. 4). Such an arrangement of multiple cones is exceedingly common and constitutes a very familiar silhouette amongst the hills of New Zealand.

We shall see later how closely analogous are the volcano and the geyser; indeed, the latter is merely a milder expression of the former, and both are due to practically the same cause, superheated water. Both, again, behave in similar fashion under similar conditions, and both tend to ultimate extinction by erecting over themselves, as it were, their own tombstones.

Thus, if the mouth of a volcano be very wide and the lava fairly liquid, it becomes a comparatively tranquil pool of boiling lava, while, if the mouth of a geyser be wide, it becomes a boiling spring, and, in the case of both, the continued deposit of fresh material round the mouth tends gradually to seal the exit. There is, indeed, in the Rotorua district one geyser which shows to perfection the interrelation of the two phenomena, namely Waimangu (fig. 5). It is hard to know whether to class this as a geyser or as a volcano, for a geyser that has a mouth fifty yards across, and that shoots boiling water and great rocks a thousand feet into the air, is hardly distinguishable from a volcano; it is truly a half-way house.

We have seen that the magma contains imprisoned water vapour.

If it flows out slowly it may emerge in treacly form as lava, a molten siliceous rock with varying proportions of alkalis and acids, but if, as usually happens, there are intermittent explosive bursts of steam the lava is shot into the air in small fragments. Under these conditions there is a sudden reduction of pressure in the ejected fragment, the imprisoned water and other gases suddenly expand, and, yeastlike, convert the stodgy mass into a spongy or bread-like substance, pumice. It is this pumice that covers



FIG. 5.- WAIMANGU IN ERUPTION.

Boiling water, mud, and boulders are being hurled over a thousand feet into the air, while great columns of steam soar thousands of feet above its topmost crest. Note the size of the hut on the hill-top.



FIG. 6.—WAIMANGU IN ERUPTION

The geyser has been snapped in the first few seconds of its sudden outburst. Before steam has hurried the outlines of the boiling liquid. Note the sharp outlines of the boiling liquid. Note the sharp outlines of the boiling liquid. Note the sharp outlines of the boiling liquid. The picture might well be mistaken for that of the explosion of a huge mine.

for many miles the plains round Rotorua, and indeed the whole thermal district.

From the crater, too, are shot fragments of rock, and clouds of rock smashed to powder—"ash"—together with gnarled and twisted blocks of comparatively solid lava in the form of "scoria," so familiar in the extinct craters of Auckland.

The alternations of bursts of these varying materials generally cause a stratification of the volcanic cone, and "sills" of lava are apt to thrust themselves through weak spots between the layers, and may reach the surface, and, discharging from the side or base of a cone, form secondary cones as already noted.

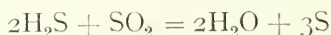
Gases emitted from Volcanoes.—In addition to lava and steam, various gases are evolved by a volcano, such as sulphur dioxide, sulphuretted hydrogen, hydrochloric acid, carbonic acid, hydrogen, and certain radio-active gases. It has been generally laid down that at no time do actual flames shoot up from a crater, but that the glare of the glowing lava, reflected on the superincumbent cloud of steam, gives a false impression of flame. This is not the whole truth, however, for hydrogen and other inflammable gases do actually burst into flame, and the flames have even been examined spectroscopically.¹ These same gases, it will be observed, are also found in connexion with volcanic hot springs.

Solfataras.—In course of time, which may be many thousands of years, or may be comparatively short, the violence of volcanic energy dies down, lava ceases to flow, and the only sign of activity is the emission of volatile vapours, the "solfatara" stage. It is in this stage of dying activity that thermal springs are most likely to be found in the vicinity, and they may continue to flow for untold ages after the solfatara stage has died down and the volcano is apparently extinct. We must add the cautious word "apparently," for mankind has occasionally learnt to its cost that a supposedly extinct volcano may reawaken.

¹ By Janssen, vide Geikie.

Gases emitted by Solfataras, Fumaroles, and Hot Springs.—

The principal gases with which we are concerned are sulphuretted hydrogen and sulphur dioxide. The chemical combination of these two causes the deposition of sulphur in crystals, which may show either as a fine glistening yellow powder painting the sinter orifice of a fumarole or geyser, or, in fumaroles particularly rich in sulphurous acid, may be deposited in masses of astounding bulk and beauty.



Percolating through the extensive beds of pumice on the shores of Lake Rotorua in the neighbourhood of the Postmaster bath, the gases deposit sulphur in large quantities in and around the pumice fragments, constituting a sulphur mine which is exploited commercially.¹

The most beautiful example of sulphur crystallization that I have ever seen was exposed when we lifted for repair the floor of the sulphur vapour bath at Rotorua. The under-surface of the boards was covered with glistening yellow spikes, from half an inch to one inch long, and thickly projecting from these were flower-like hollow cups, perhaps half an inch across and two inches long, fragile and dainty, sparkling with crystals and with moisture, and irresistibly suggesting in form and colour the Miltonian daffodils that “fill their cups with dew.”

I had a less pleasing illustration of the chemical action that goes on when these gases meet in the presence of air and moisture. With the intention of making an inhalatorium, the steam from a geyser was led into pipes, and thence into a specially fitted-up vapour room. The fumes at the geyser end were comparatively bland, being mainly steam with a certain amount of sulphuretted hydrogen, but at their destination oxidation had taken place, and an irrespirable mixture of sulphuretted hydrogen, sulphurous acid, and pure sulphur ruined my well-meant efforts.

Radio-active Gases.—So far only a limited examination

¹ The oxidation of sulphuretted hydrogen by air in the presence of water also causes the deposition of sulphur. $2\text{H}_2\text{S} + \text{O}_2 = 2\text{H}_2\text{O} + \text{S}_2$.

has been made of the radio-activity of the gases emitted from the mineral springs in New Zealand. Those examined by Dr. Maclaurin in 1911 show, of course, that the gases display a higher degree of activity than the waters from which they arise; but, as might be expected, the radio-activity of hot mineral waters is low, lower than that of the cold springs of the district. Nor has the presence of the rarer gases such as argon, neon, etc., been investigated.

Fumaroles.—Steam jets may arise not only from the immediate neighbourhood of a volcano, but at places considerably distant. Such steam-jets, or fumaroles, are very plentiful throughout the thermal district, especially at such places as Rotorua, Taupo, Wairakei, and Waimangu. The steam may issue from a hole in a rock with one unceasing roaring violence, reminding one very forcibly of a great ship “blowing off steam” (fig. 68), or it may bubble up through a layer of decomposed tuff to form a “porridge-pot” (fig. 31), or a mud volcano (fig. 28).

Explosion Craters and Lakes.—Again, instead of forming a volcanic cone, an outburst of energy may cause a lake, and there are large numbers of these so formed in the Rotorua area. When the steam is pent up by an overlying layer of tough rock, it may go on accumulating its energy until, in one terrific explosion, it bursts its bonds, hurls the restraining rocks away in scattered fragments, and forms an explosion crater. As activity dies down, the great void gradually fills with water, sometimes pure, sometimes highly mineralized, until finally a peaceful and beautiful lake alone remains to mark the grave of the extinct monster. Rotomahana in its present form was largely formed in this way.

Other lakes, such for instance, probably, as Rotorua, were formed by the subsidence of the surface after the withdrawal of immense quantities of underground material by neighbouring volcanoes, or by the blocking of river beds by the material ejected. That vast subsidences may occur may be imagined when it is considered that the single eruption of Tarawera is calculated to have ejected a cubic mile of ash.

CHAPTER III

HOT SPRINGS

THE hot springs arise in groups in more or less defined areas, generally in valleys, alongside rivers, or around lake margins, but scattered individual springs may be met with in the most unlikely places, and hot springs, and more especially fumaroles, may arise on outwardly peaceful-looking mountain-sides.

The springs vary in temperature from lukewarm to boiling, from acid to alkaline, from green to blue, but from a passing glance at a spring it is possible to deduce with some accuracy its general chemical composition.

In the first place it will be found that nearly all *boiling springs in this district are alkaline in reaction*, or at least neutral, while the acid springs never approach the boiling point. Indeed, it is rare to find a permanently acid water at a higher temperature than 160° F.¹ Where a boiling spring gives an acid reaction to litmus it will nearly always be found that the acidity is due to carbonic acid, and the red litmus paper, as it dries, and the carbonic acid gas is lost, returns to blue.

Again, the boiling springs are almost invariably slightly bluish in tinge. In small quantities the water is colourless; in bulk, as in a deep pool, it is of a clear, distinctive, and most beautiful blue, due to silicates.

A similar colour may be observed in the deep fresh-water

¹ There are, however, exceptions, such as on White Island and the Sulphur Terrace spring at Wai-o-tapu. The rule holds good, however, for the Rotorua district.

springs and underground rivers that well up so plentifully in the district, and in some lakes, such as Tiki-tapu.¹

The acid waters, on the other hand, unless discoloured by precipitated sulphur or muddy with decomposed tuff, are generally greenish in tone, the colour varying from the faint yellow tinge of sulphur to the most brilliant and vivid emerald of sulphate of iron. Such waters ooze out of the subsoil, and are never ejected with force as are many of the alkaline springs.

We will consider now the origin of the waters and of their constituents, also why some springs are boiling and some merely hot, why the boiling springs are alkaline and the acid springs are never boiling, and incidentally more particularly examine what is perhaps the most dramatic phenomenon of the district, geyser action.

Origin of the Waters.—It is not suggested for one moment that all hot mineral waters have the same kind of origin. In some the heat may be due to chemical action, some may be volcanic; but we are dealing with the waters of the Thermal District only, which are almost entirely volcanic.

We have to consider the source of the water, of its heat, and of its constituents.

The source of the water is, as we have seen, in some degree a matter of dispute. It may be due to the percolation of surface water through the superficial rocks to hot underlying strata, or it may be due to springs arising, as it were, *de novo*, from the primæval water imprisoned in the central magma.²

The heat of course is derived from contact with the

¹ Very minute quantities of silica suspended in colloid form would give this colour by reflected light. The greenish tinge of Rotokakahi is probably due to small quantities of sulphur suspended in colloidal form, and the lake is becoming less green as the sulphur is deposited from suspension. Recent experiments by Mr. Woodmansey at Harrogate show that H_2S does not decompose, with deposition of sulphur, when dissolved in distilled water and exposed to air, but does so when salts are present in the water, e.g. tap water.

² Cf. footnote, p. 16.

earth's heated interior, and in the majority of cases the temperature of the water diminishes progressively in its passage from the interior to the surface. In some cases, however, the water takes so tortuous a path to the surface that its cooling process has already progressed considerably, and it is conceivable that it may occasionally be reheated by hot superficial rocks, by steam-jets,¹ or even, as in the sulphuric acid waters, by chemical action before it emerges on the surface. Thus it will be shown that, in the case of the "Priest" springs, it is probable that the originally alkaline water is more than neutralized by the formation, quite near the surface, of sulphuric acid, and the mixture of this acid with water would most certainly mean a considerable evolution of heat.

The Constituents of the Waters.—The original chemical composition of the waters will be due to their solvent action on surrounding heated material, but this composition may be modified profoundly by further chemical action during the long passage of the water from the interior to the surface. These secondary variations will be considered later when dealing with the individual waters, but the origin of the principal original constituents can be examined here.

We have already seen that practically all the waters of the geysers and multitudinous boiling springs are alkaline; this alkalinity is due to the presence with the silicates of sodium carbonate, the other essential ingredients being sodium chloride and sodium sulphide always, sodium borate frequently, and, without exception, variable quantities of sulphuretted hydrogen. Of all these ingredients perhaps the silicates and the sulphides are the most characteristic.

Silicates.—Silicon ranks next to oxygen as the second most abundant of the elements constituting the earth's crust, of which it forms more than 25 per cent. It is also—and this is a matter which is apt to be overlooked—a most

¹ Cf. p. 38, "geysers."

important constituent of our bodies.¹ Seeing that silicon is so abundant in nature, and so widely distributed, the wonder is, not that it is present in volcanic waters, but that it is not found universally abundant in other waters. The reason is that siliceous rocks at ordinary temperatures are peculiarly resistant to the action of water,² while, on the other hand, at very high temperatures they are quite readily soluble.³ In the Rotorua springs silicon exists chiefly in the form of sodium silicate, but it may also be found combined in varying degree in different springs with other bases and metals.

Silicate-laden superheated steam approaches the surface of the earth as a fumarole, or may be condensed as a boiling spring. In either case as it nears the surface it loses in temperature, and tends to drop a large portion of its siliceous burden. Still, on arrival at the surface it is heavily impregnated with silicates, and on exposure to the air, and consequent rapid cooling, a further large deposit takes place, and we get round the mouths and funnels of blow-holes, geysers, and hot springs those silica deposits (sinter or

¹ As silicic acid is an integral constituent of connective tissue, the total amount required by the organism is very considerable, the proportion being greater in young children than in adults, thus: muscle contains 24 milligrammes per kilo of dried tissue; skin, 45; tendon, 64; dura mater, 87; fascia, 106. See also the experiments of the New Zealand Agricultural Department in feeding young lambs on sodium silicate.

² Spring water from siliceous rocks is very markedly free from dissolved mineral substances. For this reason the water supply of Rotorua is one of quite exceptional purity.

³ The most refractory silicates are easily dissolved by superheated water. Thus glass is soluble in water at 410° F. If we assume that mineral water is a "virgin water," derived from the magma, it must have been in contact, in the form of gas under enormous pressure and at a temperature of at least 1,000° to 2,000° F., with highly siliceous material. Geikie (textbook of Geology) points out that water at ordinary temperatures is a very weak base or acid, and can only to an imperceptible degree abstract silicic acid from soluble silicates. "At about 300° C. water and silicic acid are of about equal strength, at 2,000° C. water is about 300 times stronger than the acid, and will act as a powerful acid. By its action the silicates are split up into free silicic acid and bases, which by combination with unchanged magma change into acid and basic silicates."

geyserite) which are such a prominent feature of the district. The natural deposition of silica by evaporation is aided by several extraneous agencies such as living algæ and dead vegetation (cf. fig. 26).

Sulphides.—The most characteristic feature of the springs of the Thermal District is the universal rotten-egg smell of sulphuretted hydrogen. In some of the springs and fumaroles this gas is evolved very freely, in a few springs it is barely perceptible, but even in these latter it becomes more noticeable if the water is collected and allowed to get stale. The reason of this latter phenomenon is that there is always a certain amount of sodium sulphide in solution, and on exposure to the air this readily decomposes, with the evolution of the more volatile hydrogen sulphide; further oxidation of this gas causes the formation of sulphuric acid and the deposition of pure sulphur.

Sodium chloride, besides being a universally distributed salt, is found abundantly in volcanic cones and lavas; it would therefore naturally figure prominently in the analyses of volcanic mineral waters.

Sodium borate is another common product of the volcano, and is not uncommonly found in volcanic springs; indeed, in Tuscany, the recovery of boracic acid from the waters constitutes a thriving industry. In New Zealand borates have been found in several springs, notably at Taupo and at Hanmer.

Sodium bicarbonate is present in varying amount in all the boiling springs. Therapeutically its importance is obvious, geologically it is important as it enables water to dissolve silica and decompose silicates. It is one of the products of the decomposition of sodium sulphide in the presence of atmospheric carbonic acid.

Alkaline Waters.—We have seen that the “deep” springs—that is, the geysers and nearly all springs at or about the boiling-point—derive their alkalinity from salts withdrawn from the magma and deep-lying rocks, supplemented by the decomposition of sodium sulphide: we will now pass to the

consideration of the permanently acid waters, examining both their contents and whence they derive their acidity, reserving for a separate chapter a detailed account of the geysers and other hydrothermal phenomena.

Acid Waters.—Acid springs are by no means so numerous or so widely distributed as the alkaline ones, but they are found in conjunction with them in various areas of the Thermal District, notably at Rotorua, and reach their highest development in White Island, an isolated volcano in the Bay of Plenty.

As has already been noted, a water may be temporarily acid from the presence of carbonic acid gas,¹ and many of the deep springs show this temporary acidity, or permanently acid from such acids as sulphuric or hydrochloric. It is these latter with which we are concerned here.

The waters of White Island contain *hydrochloric acid* in very strong solution (3,000 to nearly 10,000 grains per gallon), and similar but weaker waters are found at Taupo. These waters have been permeated by fumes rising from volcanic vents in a state of fierce activity.

The waters of Rotorua, of Taheke, and of Whale Island owe their acidity to sulphuric acid. It is probable that, in the main, sulphurous acid, evolved from a decadent solfatar and bubbling through the waters, is the immediate agent, but from some experiments that I conducted at Rotorua, it would seem at least possible that other agencies may also have been at work in the fashioning of the local waters.

In contradistinction to the alkaline waters, which are apt to be ejected from the ground with some vigour, the

¹ Carbonic acid gas springs, generally chalybeate, are most abundant in limestone regions, and are the product of the chemical action of acids on the limestones. In volcanic districts, however, they may be due to the direct emanation of CO₂ from volcanic vents, and represent a dying stage of solfataric activity. According to Sainte-Claire Deville, the vapours evolved in the most active stage of volcanic activity contain chlorine and fluorine; in later stages, sulphurous gases; in the dying-out stage, carbonic acid and hydrocarbons.

30 THE HOT SPRINGS OF NEW ZEALAND

acid waters of the Rotorna district, such as the Priest and Postmaster springs, ooze out of the pumice subsoil of the plains that border the lake. Their outcrop is always near the lake margin, and their flow is always very definitely from the higher surrounding basin into the lake. They rise and fall with the rise and fall of the lake level, and this at first sight would seem to suggest that they are fed with surface water.

The following experiment, however, makes me incline to the opinion that they are metamorphosed alkaline waters

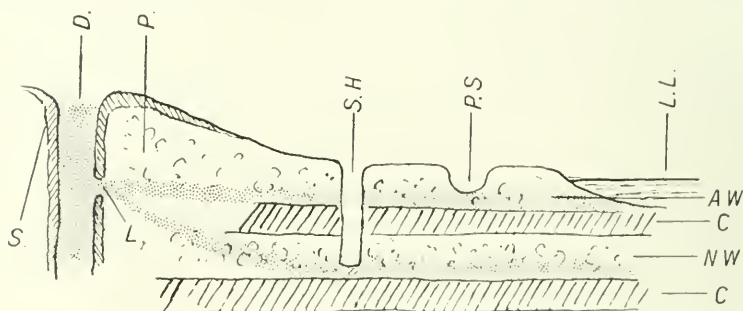


FIG. 7.— DIAGRAM OF THE FORMATION OF SULPHURIC ACID MINERAL WATER.

- | | | | |
|------|--|------|---|
| D. | Deep spring of alkaline water. | C. | Clay stratum. |
| N.W. | Neutral water. | SH. | Shaft. |
| A.W. | Acid water, in a stratum of marcasite-coated pumice. | P.S. | Priest spring. |
| S. | Silica lining. | L.L. | Lake level. |
| L. | Leak. | P. | Beds of pumice lying above and between the clay strata. |

that have escaped from the deep springs into the subsoil, and have there been acidified *in situ* by local agencies. As a natural sequence, the nascent sulphuric acid which they contain has attacked certain minerals in the superficial strata and formed fresh chemical combinations, such as sulphates of iron and aluminium.

A shallow shaft was sunk at a spot at which it was expected to find acid water. About ten feet down was struck an abundant supply of this water at a temperature of 140° F. A few feet lower was encountered a bed of white clay, forming a floor over which the hot water flowed. This was

pierced by a six-inch iron pipe, and after boring about eight feet, a mineral water was found of a temperature of 160° F., and of *neutral* reaction (vide fig. 7).

An analysis of the two waters showed that the superficial water was practically identical with the Priest spring, while the deep neutral water was closely allied to that of the alkaline Rachel spring and the geysers, and appeared to be a partially altered "deep" water, an intermediate step between the two types. While contrasting so strongly in chemical composition, however, these two waters from the shaft had one point in common in that they contained precisely the same amount of silica, even to decimals. It can hardly be conceived, therefore, that unless they had originally one common source, they would have possessed this absolutely common factor. I believe, therefore, that the acid springs represent alkaline waters that have escaped through faults in their channels into the subsoil, and, owing to peculiar local conditions, have there been made acid by oxidation.

We will now examine these local conditions.

In the first place, a deep pumice bed would seem an ideal oxidizing medium; but as the pumice at the spring level is waterlogged, one could not expect much air to be imprisoned in its meshes. Being aware that marcasite (FeS) is one of the natural agents that oxidize sulphides into sulphates, I closely examined the stratum of pumice through which the hot water flowed, and found that much of it was blackened. Portions of this pumice sent for analysis revealed the fact that the black coloration was due to minute crystals of marcasite about $\frac{1}{100}$ inch in diameter.

Another local source of sulphuric acid is, I believe, the percolation of fumes of sulphur dioxide through the water as it runs in its pumice bed.

We have now seen the genesis of an acid water from an alkaline: the presence of sulphates of iron and aluminium is explained by the subsequent action of sulphuric acid on clay and iron ore.

32 THE HOT SPRINGS OF NEW ZEALAND

As to why the local acid waters are always considerably below the boiling-point, the question has already been answered in the preceding paragraphs. If we assume that the acid water is merely boiling alkaline water that has travelled through tortuous superficial channels of comparatively cool pumice, we can easily understand that it must necessarily have parted with a good deal of its heat, and may even have become quite cold. The chemical action, however, of newly formed sulphuric acid on the water would heat it again considerably, but not to the boiling-point.



FIG. 8.—A SMALL GEYSER, WHAKAREWAREWA.
Stalactite masses formed by the overflow into the river of some larger geysers on higher ground.

CHAPTER IV

GEYSERS AND BOILING MUD SPRINGS

THE most dramatic phenomenon in the Thermal District, and undoubtedly the feature of most immediate interest to the casual visitor, is the geyser. There are in this district some half-dozen large, and quite a number of small, geysers to be seen in active operation, while the dry siliceous mouths, the skeletons, as it were, of extinct geysers, may be found by the score.

There is something grand and elemental about a big geyser. The sudden fierce outburst of steam, the resistless hurling aloft of a great column of boiling water, the fierce roar as it bursts its bonds, the tremor of the hot rocks beneath one's feet, all combine to arouse a feeling akin to awe in the beholder. One almost forgets that this is a phenomenon of inanimate nature and feels rather in the presence of some monstrous, beautiful living thing rising terrible in its wrath.

It is not until all is over, not until, in great sighing gasps, the monster has sunk back exhausted into its silica cave, that one is minded to question into the why and wherefore. But, man being what he is, it then becomes a matter of almost as great interest to probe into the means as to watch the result.

The most salient features of a geyser are that boiling water is shot into the air, that the action is intermittent, and that in some cases the action is repeated with clock-work regularity. This regular intermission is not a necessary feature, and indeed is absent in the case of the Rotorua geysers, though present in some in the Taupo-Wairakei

area; and finally, some small geysers are almost continuous in their action.

The generally accepted explanation of geyser action is based on the investigations of Bunsen and Descloiseaux, who recorded the temperatures at varying depths in the tube of the Great Geyser of Iceland. The explanation given here is a summary of the accepted view, but modified somewhat by the personal observation of the author.



FIG. 9, A.—FUMAROLE OPENING ON A STEEPLY SLOPING SURFACE.

This generally persists as a fumarole, but even on a cliff-face it may sometimes form a hot spring, as in fig. B.

The only essential mechanism in the formation of a geyser is a subterranean supply of either steam or water, heated to a point well above the surface boiling-point, and a tube or funnel communicating more or less vertically with the surface and of a comparatively small sectional area.

Given sufficient water, of sufficient

temperature, and a sufficiently long and narrow exit tube, it will be shown that geyser action is not only possible but inevitable. It was formerly thought that the intervention of a subterranean cavern was a necessary part of the mechanism, both to act as a reservoir for the water and to afford with its dome-like roof space for an elastic cushion of steam. We believe now that no cavern is necessary, though, as will be shown later, in the case of

one extinct geyser such a cavern is actually interposed. It will perhaps be easier to understand the mechanism of a geyser if we trace it back to its genesis—a fumarole.

Fumarole.—Superheated water-substance,¹ escaping from the white-hot magma, finds its way through some narrow passage in the solid crust. It is improbable that any actual open passage can exist in the lower depths, but that rather the heated gases percolate through unbroken material. As the heated gas approaches the surface, and the pressure on it, and also its temperature, diminish, a point is reached at which the formation of steam is possible. This superheated steam will cool gradually as it passes by tortuous crevices to the open air, where it finally emerges as a fumarole or blow-hole. Should now the surface of the ground be sloping, the condensed water from the steam-jet runs away, and the fumarole continues as a “blow-hole” (cf. fig. 9, A, also fig. 68, Kerapiti Blow-hole).

Evolution of Boiling Spring.—Should, however, the surface



FIG. 9, B.—FORMATION OF HOT SPRING FROM A FUMAROLE ON A CLIFF-FACE.

The steam erodes the upper wall of the pipe and deposits silicates on the lower rim, gradually forming a basin in which boiling water collects. Examples may be seen at Wairakei.

¹ For those who deny the physical possibility at such a temperature of dissociated water-substance, we can substitute “superheated hydrogen,” which would become oxidized in the more superficial strata. There is of course the alternative theory of Brun that fumaroles are due to the percolation of surface water to heated rocks, and have altogether a more superficial origin (cf. footnote, p. 16).

be nearly flat, water collects about the mouth of the fumarole, and a ring of silica is gradually deposited around it. In this way a basin is built up, which fills with condensed water (fig. 9, D). Should the basin be relatively large, the water in it may cool sufficiently to check the exuberance of the fumarole by running down its pipe. A condition of equilibrium is reached, and an ordinary boiling or hot spring

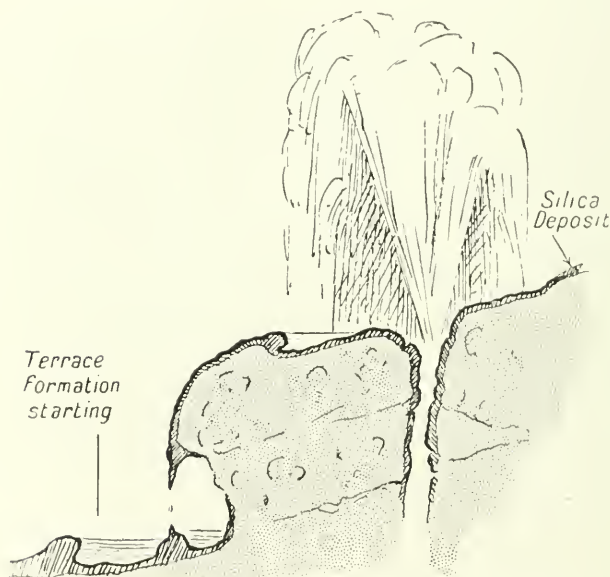


FIG. 9, c.—FUMAROLE ON GENTLY SLOPING SURFACE.

The fumarole may occasionally persist, but more often results in the gradual formation of a hot spring. Note the terrace formation (cf. fig. 8).

results (vide fig. 9, D). Such a boiling spring may also result if the steam in the fumarole condenses before reaching the surface.

Formation of Small Continuous Geyser.—The condition of equilibrium is, however, somewhat unstable, so that a spring may be sometimes a boiling cauldron and at other times a geyser. Thus, should the water be just insufficiently cooled to dam back the fumarole, we get a continuous geyser of small altitude, such as Papakura, in which boiling

water is shot in pulsating but otherwise continuous fashion some three or four feet into the air (vide fig. 11).

There is every gradation from the boiling spring through the foregoing continuous geyser to the true geyser.

Formation of True Geyser.—Finally the fumarole may become a true geyser. In this case the water which has condensed at the mouth of, or in the pipe of, the fumarole



FIG. 9, D.—FUMAROLE ESCAPING ON HORIZONTAL SURFACE.

A ring of silica is deposited which gradually constitutes the rim of a pool of hot water.

R, rim : darker shading indicates recent deposit of silica.

is sufficient to dam back the uprising steam. As a result the water soon boils fiercely, and, becoming superheated at its lower depths, bursts into steam, and geyser action is started. The geyser may conform to one of two types : it may be regularly intermittent or it may be irregularly intermittent. The reasons for the regularity or otherwise of the intermissions we shall appreciate better after we have examined the mechanism of a geyser.

A geyser may open on the surface into a pool of hot water,

like the Twin Geysers at Whakarewarewa (figs. 13, 14) and the Great Geyser of Iceland (fig. 10), or it may have rounded, dry masses of "geyserite," pouting lips as it were to its mouth, and no pool (fig. 15) like Pohutu and Wairoa geysers at Whakarewarewa (cf. figs. 1 and 23).

The diagram (fig. 10) represents the Great Geyser of Iceland, a geyser with a surface pool. Here is a tube T,

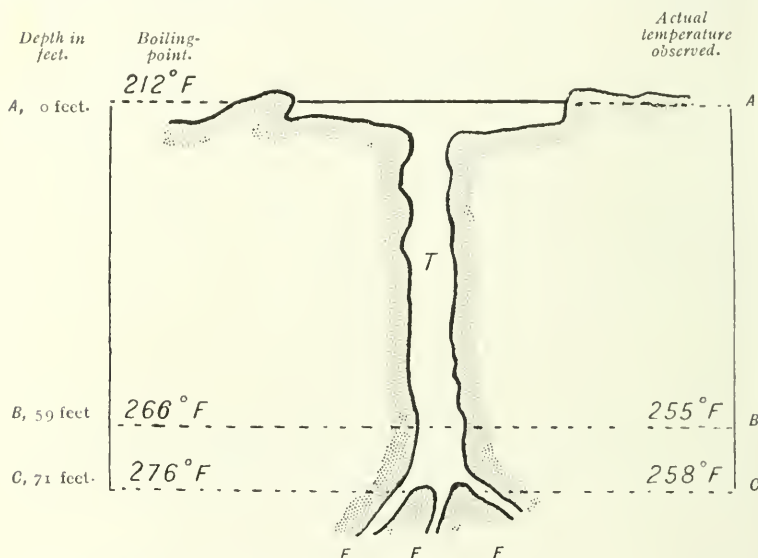


FIG. 10.—DIAGRAM OF THE GREAT GEYSER OF ICELAND, A TYPE IN WHICH THE TUBE OPENS THROUGH A BASIN.

The figures on the left represent the theoretical boiling-points at different levels; those on the right the actual temperatures registered by the thermometer at those levels.

some 70 feet deep, into the lower part of which superheated water or steam enters. The water at the surface boils at roughly 212° F.; 25 feet down, under the correspondingly increased pressure, it boils at 230° F.; 59 feet down it boils at 266° F. Now if water from the lowest depths were brought suddenly to the surface it would boil with such instantaneous violence as to make it practically a high explosive. Or if, on the other hand, the water 59 feet down were, by a sudden incursion of superheated water or steam,

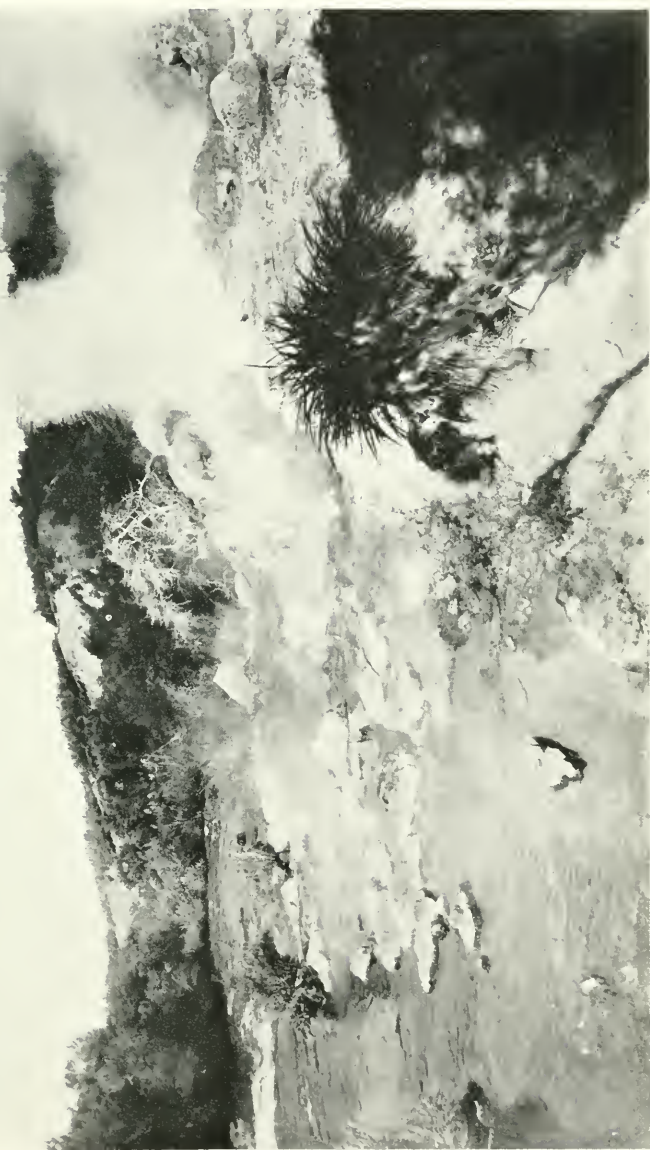


FIG. 11.—PAPAKURA GEYSER, ON THE BANK OF THE PUARENGA RIVER, WHAKAREWAREWA. THIS SMALL GEYSER IS ALMOST CONTINUOUS IN ACTION.



FIG. 12.—A CLOSE VIEW OF THE MOUTH OF PAPA KURA GEYSER. THE SILICA DEPOSIT IS REMARKABLE FOR ITS BEAUTY OF COLOURING.



FIG. 13. A GEYSER OPENING THROUGH A POOL OF BOILING WATER.
Behind it, obscured by the steam, is a lake of boiling water: the foreground is a thin crust of silica undermined and honeycombed by boiling water. On the hills in the background are the Government nurseries of forest trees, Whakarewarewa.



FIG. 14.—ANOTHER VIEW OF THE SAME GEYSER AND BOILING LAKE AS IN FIG. 13. THE SPECTATORS ARE
STANDING ON A THIN CRUST OF SILICA.



FIG. 15.—THE MOUTH OF AN EXTINCT GEYSER, WHAKAREWAREWA, A GEYSER OF THE DRY-MOUTHED TYPE.



FIG. 16.—THE "BRAIN-POT," WHAKAREWAREWA, THE CONE OF AN EXTINCT GEYSER. According to tradition, a Maori warrior cooked his adversaries' brains in this "pot," presumably when it was in the dying-out stage of a fumarole.

raised in temperature, say, 10 degrees above its boiling-point, it would burst into steam and shoot up the superincumbent column of water as a geyser. The same result would follow if, say, six feet of water were baled from the top, for with the diminished pressure the deep water, which formerly was just below its boiling-point, would suddenly find itself well above that point, and would at once explode into steam. These are the factors of geyser action.

Superheated water enters, say, by the fissure F. The water at B, which normally boils at 266° F., is suddenly raised, say, to 280° F. It boils furiously, and shoots out the water above it. In so doing, it empties the top of the tube T, and lessens the pressure on the deeper water at C. This in turn suddenly finds itself above the boiling-point, and is ejected, while more water flows in from the fissures FF, and the more readily as these also are now under lessened pressure. And so the process goes on until the reservoir of water is exhausted.

If, however, there is a basin at the mouth, considerable quantities of partially cooled water collect, and, as the violence of the geyser lessens, begin to run down the mouth and cool the water in the tube. The geyser then subsides for a time, until this cooled water is again brought to the boiling-point, when the cycle recommences.

Thus we get regular intermission. But regularity of action may be brought about in other ways, for some geysers with no basins may yet be regular in their action. It is conceivable that this may sometimes be brought about by the manner in which steam bubbles rise through the magma. If you take a long tube, say a test tube, of some thick fluid and apply heat to the bottom until it boils, steam will be evolved, not in one continuous stream, but in a series of bubbles, and the thicker the liquid and the longer the tube, the larger the bubbles and the more explosive their bursting force. Now take what is practically a test tube many miles deep, filled in its lower part with molten magma through which heated water-gas is bubbling. The bubbles

will tend to be fairly large, especially as they approach the surface, and will tend to rise in fairly regular intermission. Such a bubble coming in contact with the deepest layers of superheated water will cause it to boil very rapidly. The rapidity of the process will be much enhanced by the fact that the steam, on meeting the water, will evolve its "latent heat." This starts geyser action, which continues until the available reservoir is exhausted. The next great bubble of steam will then repeat the process.

The curious and hitherto unexplained feature is the

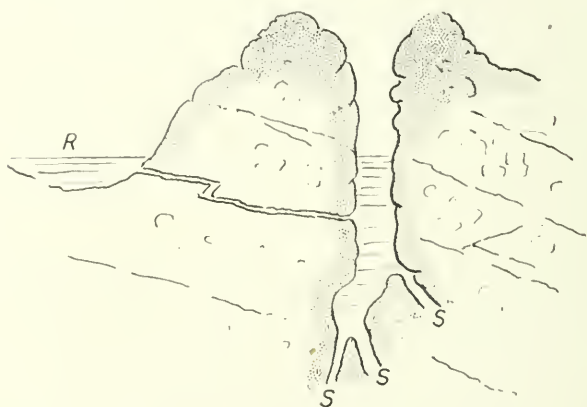


FIG. 17.—DIAGRAM OF GEYSER, QUITE QUIESCENT BETWEEN OUTBURSTS, IN HYDROSTATIC CONNEXION WITH NEIGHBOURING RIVER, R.
SS, passages conveying steam. The shaded area represents siliceous deposit.

absolute quiescence of some geysers between the bursts. Thus, at Whakarewarewa, Pohutu, and Wairoa, during their often prolonged periods of inactivity, are ordinary quiet holes in the rocky ground, with scarcely a trace of steam coming from them. Why?

I think the reason is that cold surface-water has access to their tubes and shuts down the geysers like a valve, until it in turn is boiled by the increasing volume of steam from beneath. It is suggestive that both here and at Wairakei, Taupo, and Orakei-Korako the geysers are all close to the banks of rivers (vide fig. 17).

To sum up, then, the view here advocated is that geysers—at any rate the geysers of New Zealand—are fumaroles whose steam has condensed into boiling water in the geyser tubes ; and that this water is from time to time superheated by the access of fresh bursts of steam to a temperature above its boiling-point. In some cases, at any rate, the working of the geyser is modified by cold surface-water which exerts a restraining or valve action, and which is in its turn superheated by the steam.

The above explanations of geyser action are based, it must be admitted, on comparatively limited data. It is of course impossible to explore the recesses of an active geyser, and still more so to take a Jules Verne expedition to the central magma, which holds really the key of the situation, and the structure of a geyser has therefore been more or less of the nature of a conjecture based on close observation of its working. From observation of effects we can deduce probable causes, but many points are still arguable.

Luckily there is at Rotorua an extinct geyser, which has been to some extent explored, and from its skeleton we are able to check some of our theories.

It is situated at Whakarewarewa, in the very heart of the hot springs and geysers, extinct and active, a circular hole with the typical rounded sinter edges of a geyser, just large enough for a man to squeeze his body through. He needs must be a brave man too, with violent boiling springs within a few feet all around threatening at any moment to flood the orifice, and I must confess that I myself preferred to get my evidence without personal exploration and therefore cannot vouchsafe for the entire accuracy of this description.

The mouth of the geyser, then, apparently leads down a short tube into a small vaulted cavern, into the floor of which open small passages by which the steam or hot water must have entered. The walls of the tube and of the cavern are lined by smooth, bossed masses of silica.

As we have already seen, it is not suggested that the cavern is a necessary and essential part of the mechanism : so long as the geyser tube is capacious enough to act as a reasonable-sized reservoir the cavern might be dispensed

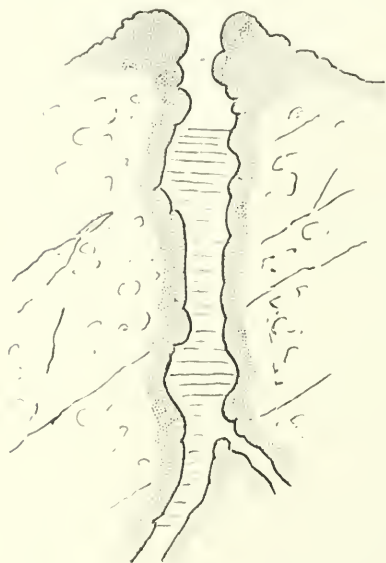


FIG. 18.—DRY-MOUTHED GEYSER, WITH NO GEYSER BASIN.

with, and on theoretical grounds there is reason to believe that the lower part of the geyser tube is a good deal more capacious than its mouth (cf. fig. 18).

It might be thought that a geyser was sufficiently awesome to be left by mankind severely alone, but familiarity breeds contempt, and man, ever inquisitive and interfering, has not long hesitated to lay sacrilegious hands upon even it ; and so it comes about that he has discovered that its action can be controlled. The geyser can be tamed, as can be any other wild beast, and incidentally the taming process has served to corroborate some of our theories.

As we have seen, if we can lighten the load on the water in the depths of the geyser tube, we reduce the boiling-point of the water, and this water, which was in equilibrium just below its boiling-point, suddenly finds itself above that point, bursts into steam, and starts geyser action.

We can reduce the load in two ways : we can bale off some of the top water, or we can lower the specific gravity of the water in the upper part of the column—in other words, make that water lighter. Both these methods are employed by the guides when they wish to make a geyser “ play.”

Fig. 19 represents a small geyser on the banks of the Waikato, near Taupo. Normally it is a boiling pool, but by removing the plug P from the side of the spring the water-level is lowered and the spring becomes a geyser.

The other method is to pour soap into the geyser tube. In the geyser tube a foaming mass of soapsuds quickly forms, and as quickly boils over. A cubic foot of soapsuds is a good deal lighter than a cubic foot of water, and consequently the pressure on the deep water is rapidly lessened, the boiling-point is lowered, and geyser action is started. Somewhat similar tricks are played with fumaroles and with hot springs. Thus, if a piece of lighted paper be held over the mouth of a languid "blow-hole" it starts into brisk activity. The heated air from the flaming paper rises and causes a momentary lessening of atmospheric pressure over the mouth of the fumarole and on the escaping steam.

The same effect is exemplified on a large scale in bad weather. With a fall of the barometer all the hot springs and fumaroles become more active, and if, as is usual with a low barometer, the air is moist, the steam becomes more quickly condensed,

and hence more visible. Thus, on a fine hot day Whakarewarewa may show isolated puffs of white steam, in wet weather it is almost hidden in a cloud of vapour. In hot springs containing much dissolved gas it is the custom of

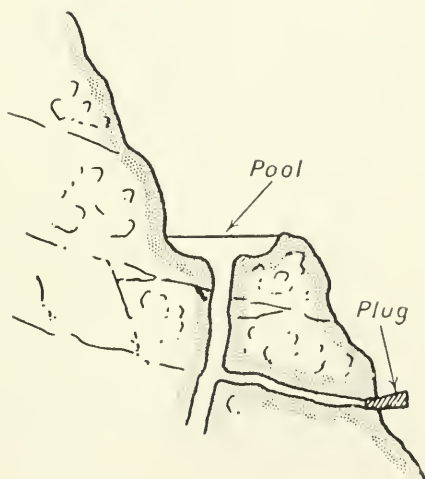


FIG. 19.—BOILING SPRING ON BANKS OF
WAIKATO RIVER.

This spring can be converted into a geyser by removal
of the plug.

the guides to "make the water boil" by throwing in it a handful of fine gravel. Gas bubbles collect and cling to each particle of sand, and disengaging, the hitherto quiet pool is soon in a state of brisk effervescence. The phenomenon, with the help of crumbs, is familiar to drinkers of champagne, and so such pools get to be known as "champagne pools" (fig. 21).

A geyser may not only be made to play, but may be damped down. There is a small geyser in the Sanatorium Gardens at Rotorua which is utilized to supply hot water



FIG. 20.—DIAGRAMMATIC SECTION OF THE CONE OF A "DRY-MOUTH" GEYSER
G.T., Geyser-tube. G, Geyser mouth. T, Terrace formation.

to the Blue Bath (fig. 22). When it is necessary to repair the pipes leading from it, a hose is turned into the geyser mouth, and all action can be stopped for days together.

Silica.—No account of the geysers and hot springs would be complete without some mention of the wonderful and beautiful sinter structures built up by the agency of siliceous waters. The inside of a geyser tube, in so far as we can view it, consists of a thick deposit of silica, generally rounded in knobs from the size of an orange to that of a football, with smooth surfaces polished by the friction of boiling water and steam (vide figs. 18 and 20). At the mouth these expand into rounded hemispherical lips, smooth on their inner or tube surface, and gradually becoming, on their outer



FIG. 21.—A "CHAMPAGNE POOL."



FIG. 22.—THE MALFROY GEYSERS, SANATORIUM GARDENS, ROTORUA.

A boiling spring has been converted artificially into a geyser by the judicious use of concrete. The boiling water is thus made to pump itself to the higher level required to feed the Blue Bath, while the steam is utilized for warming buildings and for vapour baths.



FIG. 23.—WAIROA GEYSER, WHAKAREWAREWA.



FIG. 24.—PART OF THE GREAT TERRACED CONE OF WAIKITE GEYSER.



FIG. 25.—A SILICA TERRACE, WAI-O-TAPU, DEPOSITED BY THE OVERFLOW OF A BOILING SPRING. The delicate wet silica tracery is iridescent with glowing colour, heightened by yellow masses of sparkling crystals of sulphur.



FIG. 26. —A SOLIDIFIED MASS OF SILICATED TWIGS AND LEAVES OF A
NATIVE SHRUB.

The deposit was removed from the wet soil beneath the still vigorous parent plant.

or peripheral surface, more and more rough with an intricate pattern of silica ripples. These rounded lips form a geyser cone, and in a geyser of any size and age are themselves raised on a broad, blunt cone of terraced platforms. As more and more water is poured out, and ever fresh silica deposited, the height and girth of the cone increase, exactly as in a volcanic cone, until a veritable hill of silica is formed, perhaps some forty feet high and a couple of hundred feet in diameter (fig. 24). The semi-extinct geyser Waikite is a perfect example. As a result of its own activity the geyser



FIG. 27.—THE FRETTED FLOOR OF A SILICEOUS POOL ON
A GEYSER TERRACE.

has now to shoot an extra forty feet before it reaches the open air, and in the tube above the ground-level its walls are comparatively cold. For this reason, not only is more silica deposited in the tube, thereby choking it, but the cooled water damps back geyser action, and the geyser becomes extinct, its energy finding a fresh and perhaps distant outlet. Thus every geyser, like every living creature, has a time limit to its life.

The terraced platforms of the cone are inlaid with shallow pools, whose floors and rims are covered with a network of raised silicate tracery of elaborate and often most exquisite

design (vide figs. 26 and 27). Here and there are deeper pools, as if Nature had intended to provide a sumptuous bath, while at the rounded margins of the terraces there is a tendency to the formation of stalactites, stalagmites, and fluted columns. On a heroic scale, such was the construction of the lost Pink and White Terraces.

In a minor degree we see the same deposition of sinter

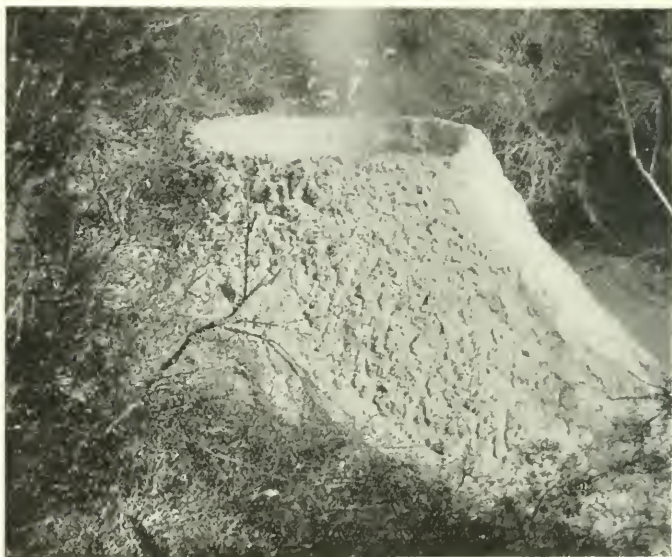


FIG. 28.—A MUD VOLCANO IN ACTIVE ERUPTION.

The height of the cone was about seven feet, and it persisted for several years, in spite of denudation by heavy rainfall. Rotorua district.

around all the hot springs of this district. Sinter or geyserite is deposited from siliceous waters as they cool; where on the margins of pools there are growing mosses, grass, twigs, or roots, these are rapidly coated with silica, and, getting welded into a conglomerate, materially assist in the sinter architecture (cf. fig. 26). Naturally, round the extreme margins of pools, where the water is most cooled, the deposition is greatest, and here too, where the water is hot but not boiling, the deposition of silica is assisted by the

action of algæ.¹ These, by some process of acclimatization, appear to flourish in water at surprisingly high temperatures, and can exist in the partially cooled water at the margins of pools, and on their death, become silicated up in coral-like masses, thus aiding materially in the formation of the beautiful scalloped edges that rim the pools.

Silica again may be deposited on projecting rocks, boughs, and fallen tree-trunks, eventually completely covering them and fringing them with stalactites. In this way curious and sometimes weird and grotesque shapes are evolved (cf. Dragon's Mouth, fig. 66). An example of this, where man has discreetly aided nature, may be seen in the Eagle's Nest Geyser (fig. 73).

Hot Mud Springs.—While geysers compel our respectful admiration, the boiling mud pools fascinate by their very repulsiveness. We have seen that there is a substratum of clay, derived from decomposed siliceous rocks and volcanic tuff, underlying considerable areas in the Thermal District, and in places this clay outcrops on the surface and may form high hills. It is of the finest quality, and varies in colour from the pure white of kaolin,² through grey, yellow, and red, to brilliant purple. Through this clay fumaroles are emitting steam, churning up the clay into "porridge-pots" (fig. 31). Such boiling mud holes are generally found at the bottom of shelving pits of pumice and clay (fig. 30), enlarged by the falling in of their crumbling sides into the bottomless morass, but may also occur surrounded by sinter (fig. 29), or even covered by this rock and apparent only through fissures. They bubble and churn fiercely, splashes of hot mud being thrown intermittently a foot or two into the air, to fall back on to the oily surface of the pool with a sullen and ominous "plop." The natural oily surface of the liquid mud is often enhanced in its oiliness by a thin layer of

¹ W. H. Weed, 9th Annual Rep. U.S.G.S., 1889. *Amer. Journ. Sci.*, xxxviii (1889).

² Kaolin consists of Al_2O_3 about 40 per cent., CaO about 3 per cent., SiO_2 about 43 per cent., and H_2O about 14 per cent.

petroleum. As bubbles of steam rise to the surface they burst, often with the formation of flower-like fountains of mud—the sort of lilies one might expect to see adorning a medieval hell (fig. 31). Such pools may be seen at their best—or worst—at Tikitere and at Arikikapakapa near Rotorua (vide fig. 32). Often, too, there is a peculiar penetrating odour of cooking bacon about these pools, an odour which I am totally unable to explain, but which calls up involuntary suggestions of hidden culinary tragedies!

In places where the mud is especially thick and tenacious it is built up into miniature volcanoes (figs. 28 and 35), frequently from two to six feet high, but occasionally, as at Wai-o-tapu (fig. 60), of very much larger proportions. The mud on the outside of these cones—which, by the way, are built up in precisely the same way as ordinary volcanic cones—dries and hardens under the sun, and such volcanoes may persist for many years. The smaller ones generally liquefy under heavy rain and become again “mud pools.” In the age-long churning and sifting by steam bubbles, every trace of grit and stone is wholly sifted to the bottom and eliminated, so that the mud remains as a smooth, bland unguent, which dries to an impalpable greasy powder. This mud is ideal in consistency for therapeutical purposes, and makes most excellent and soothing baths.



FIG. 29.—A POILING MUD POOL, LOCALLY KNOWN AS A "PORRIDGE-POT."
Note the large domed bubble of mud just ready to burst. This spring is confined by hard slater walls.





FIG. 39.—A TYPICAL BOILING MUD POOL OPENING THROUGH A HORIZONTAL CLAY STRATUM.
Note the confining walls are only of dry cracked mud. Such mud is the usual basis of the mud baths.



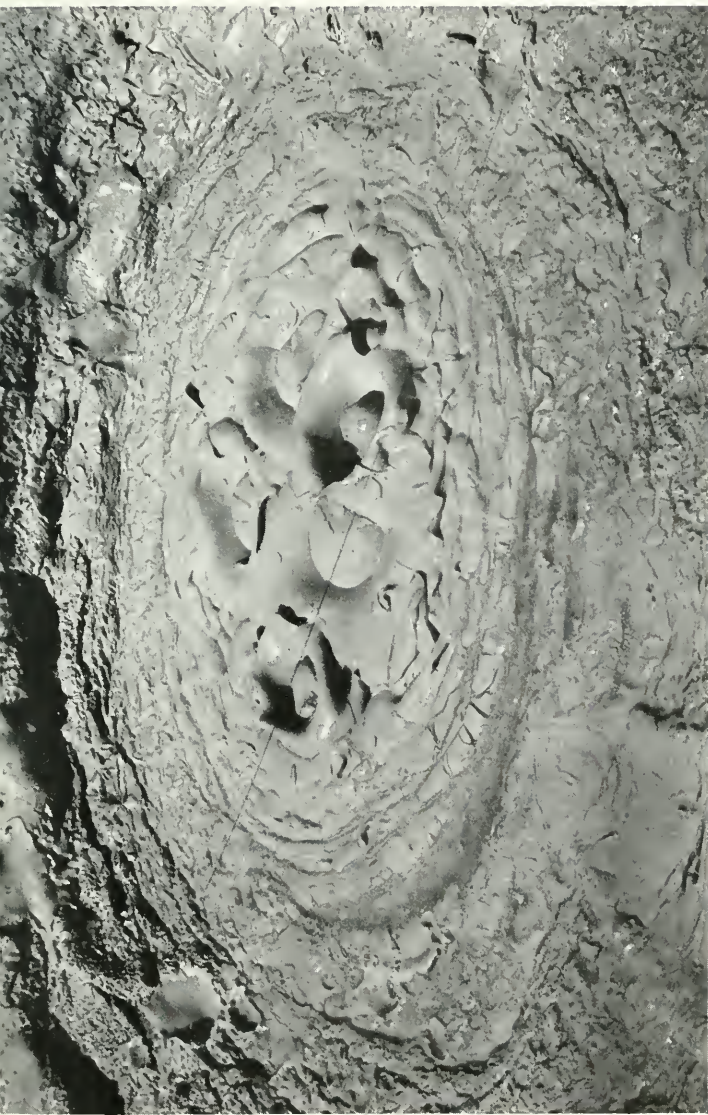


FIG. 31.—A UNIQUE PHOTOGRAPH OF THE SURFACE OF A "PORRIDGE-POT."

The formation of the lily-like shapes can be traced through its various stages. First a steam bubble raises the mud in a glistening dome; this bursts, and the outcurving segments form the "petals" of the "flower," while the steam-jet of the fumarole shoots "stamens" through its centre: the ensuing bubble rises to form a "pistil." Such flower-forms arise without ceasing on the surface of any fiercely boiling pool, and fascinate with their endless variety of shape, and often even of beauty.





FIG. 32.—“THE INFERNO,” TIKITERE, NEAR ROTORUA.

A group of large boiling mud pools, black, sullen, and repellent in their hideousness, but at one time much used for mud baths.





FIG. 33.—CONES OF MINIATURE MUD VOLCANOES ARISING THROUGH THE FLOOR OF A SHALLOW COLD LAGOON.



FIG. 34.—A STUDY OF MINIATURE MUD-VOLCANO CONES



FIG. 35. THE SAME CONE AS IN FIG. 28, IN A QUIESCENT STAGE AND PARTLY DRIED.

PART II
BALNEOLOGICAL

CHAPTER V

THE MINERAL-WATER HEALTH RESORTS—SPAS

WHILE New Zealand is a country peculiarly rich in mineral springs, and especially in thermal springs, there are only three or four places that have yet reached such a stage of development as would entitle them to be dignified with the name of spas. Of these, Rotorua, Te Aroha, and Hanmer are managed by the Government, and Rotorua alone can be considered fully equipped in accordance with European standards.

When we consider that less than a hundred years ago the country was literally in the Stone Age, and that even now its population is little more than a million, it is surprising, not that development is incomplete, but that so much has been done and so high a standard reached.

In addition to the three government spas there are numerous smaller health resorts that have been started by private or municipal enterprise, with or without government assistance. Thus, north of Auckland, the saline springs of Helensville are gradually being developed by local enterprise, while Waiwera on the east coast and Kamo, with its wonderful carbonic acid gas springs, have baths and hotel accommodation.

Farther south, on the east coast, are the unique thermal iodine waters of Morere and Te Puia. Inland, in the Wai-kato district, is Okoroire, while in the thermal district are Taupo, Wairakei, and Wai-o-tapu. There are, in addition, numerous places boasting springs that would make the reputation of a European city, whose primitive baths at present serve only local needs.

All these are health resorts in the making, potential spas, and their ultimate fame and prosperity are assured as population increases.

It will perhaps be most convenient to describe these places in groups corresponding roughly to their mineral-water classification.

Sulphur Waters.—Rotorua, Hanmer, Taupo, Wairakei, and Wai-o-tapu, all, with the exception of Hanmer, in the thermal district.

Alkaline Waters.—Te Aroha.

Saline Waters.—Helensville, Waiwera, and Tarawera.

Iodine Waters.—Morere and Te Puia.

Calcium Carbonated Waters.—Kamo.

Simple Thermal Waters.—Okoroire, and the Waikato springs.

THE SULPHUR WATER SPAS

These comprise Rotorua and all there sorts of the Thermal District ; and though of all these places Rotorua alone can be considered a spa in the modern acceptance of the term, with full facilities for balneological treatment, yet there are numerous other centres where may be found wonderful hot springs and baths which, though simple in construction, have a special fascination from their very simplicity.

At these " natural " spas one may bathe in hot water in the most primitive of huts, or, better still, in the leafy shade of overhanging boughs, or in a rocky basin under the stars (fig. 36).

With only a bath-towel for equipment, and with no bother about tickets and attendants and prescriptions, one can enjoy a bath in all its prodigality of mineral water and with the invaluable adjunct of freshness both of water and air, which the bather in the prosaic civilized bath never tastes. The ubiquitous sand-fly alone disturbs the prevailing harmony and peace.

Such conditions conduce to rest of mind and body, and for the tired dweller in towns are often more efficacious



FIG. 36.—HINEMOA'S BATH.

A natural warm pool on the shores of Mokoia Island in the centre of Lake Rotorua. It was in this bath, according to tradition, that Hinemoa rested and recuperated after her long swim from the mainland to join her lover. It is a typical example of a Maori bath.

than the best-planned and most elaborate arrangements of an up-to-date spa.

There is too the advantage of an alfresco sun and wind bath. It is as the difference between a swim in the open sea, with buffeting surf to meet and the open shore to dress on, and the ordered comfort of a first-class swimming bath.

In addition there is always the diversion of many and weird thermal "sights," though the adventurous are advised not to explore too incautiously without a guide.

"Natural baths," generally of Maori origin, may be found over an area of more than a hundred square miles, but the principal baths are congregated at Rotorua, with its Maori suburbs of Ohinemutu and Whakarewarewa, and at Wai-o-tapu, Wairakei, Taupo, and Tokaanu.

CHAPTER VI

THE SULPHUR SPAS

ROTORUA

ROTORUA, a small town of some 3,000 inhabitants, is the chief place in the Thermal District, the principal spa of New Zealand, and the principal tourist centre. It takes its name from the lake¹ on whose shores it is built, and is laid out in American fashion in rectangular blocks and broad straight streets. Being purely a tourist resort, it consists mainly of boarding-houses and hotels. To the north and south of it are the ancient Maori villages of Ohinemutu and Whakarewarewa,² flimsily perched around, between, and sometimes actually upon, boiling springs and fumaroles on ground that seems to the uninitiated totally unsafe to walk upon. It was of course the presence of these springs that originally determined the native settlement, for as in Europe wherever there is a hot spring there may be found a trace of Roman occupation, so in New Zealand wherever there is a hot spring there will be found a Maori whare.³ The boiling springs and fumaroles serve to cook all the food, to wash all the clothes, and to supply primitive but luxurious open-air hot baths. In the cold days of winter there was no need to trouble about fires—a real trouble in the days before matches—but one could wallow luxuriously in a hot pool by the hour together while the kumaras⁴ cooked

¹ " Rōto "—a lake ; " rua "—two, twin, or second.

² " Rewa-rewa "—mist, steam ; " whaka "—a causative, something that makes the steam rise.

³ A hut.

⁴ Sweet potatoes.

in a fumarole alongside. It is no wonder that the Maori built alongside the hot springs. These native villages, though now decadent and semi-European, add a vivid touch of the picturesque, particularly welcome in the somewhat matter-of-fact and prosaic life of a modern English community.

The Hot Springs.—There are three main groups of hot springs.

At Whakarewarewa are the far-famed geysers, hundreds of boiling springs, fumaroles, and boiling mud pools, and one great pool of boiling water that almost deserves its name of a “lake.”

At Ohinemutu there are exactly the same phenomena, but thermal activity is somewhat less fierce; geysers, which used to figure prominently in purely Maori days, are here apparently extinct, and the boiling springs are surrounded to their edges by peaceful vegetation; there is too a hot lake, but it is not actually boiling, and tea-tree flourishes to its very margin. The third group lies between these two at Rotorua proper, and, though not so abundant in output or so fierce in activity, is yet of such value on account of the unique combination that it offers of absolutely distinctive and unlike thermal waters, that it determined the site of the town. Indeed, there is probably no spa in the world so rich in hot mineral waters covering so wide a range of therapeutic possibilities. On the one hand there are the alkaline siliceous sulphur waters, arising in immense quantities from a large number of springs, at or near the boiling-point, and each differing in minor details of analysis from its neighbour; on the other, there are strong sulphuric acid hot springs, more circumscribed in area and output, but quite unlike any waters known in Europe, and possessing unique powers of stimulating the cutaneous circulation when used as a bath. Then there are the hot mud springs, consisting chiefly of silicates with a large proportion of free sulphur, which are used for “fango” baths; the fumaroles charged with sulphuretted hydrogen and those

charged with sulphurous acid, both of which are used for vapour baths; and finally there are tepid sulphuric acid springs, bubbling with free carbonic acid gas.

All these natural resources combine to build up the reputation of Rotorua as a *bathing* resort, but it is on the sulphuric acid baths, the Priest and Postmaster, that that reputation chiefly rests. Only in drinking waters is the spa deficient, the alkaline sulphur waters alone being available, supplemented by the valuable waters transported from Te Aroha.

Access.—By train from Auckland or Wellington: the former a journey of eight hours, the latter a long and tedious pilgrimage of some sixteen hours. There are, however, sleeping- and dining-cars on the train whereby the journey is shortened materially. Those who prefer a less conventional trip can come by motor from Napier through Taupo, and so through the heart of the thermal district, a most interesting trip; or, if coming from Wellington, can take the Wanganui River *en route*.

Climate.—The climate of Rotorua is determined first by general geographical conditions, latitude, the surrounding ocean, and prevailing winds, which affect the climate of the country as a whole; then by local conditions, which have perhaps an even more potent influence.

Situated in latitude $38^{\circ} 8' S.$, an equivalent in Europe to that of the south of Spain, there would naturally be a fairly warm climate were there not important modifying local features. New Zealand, surrounded by the largest expanse of ocean on the globe, has essentially an island climate, equable and mild, with a minimum contrast between day and night temperatures and between winter and summer, and the North Island is itself so comparatively small that no part of it is sufficiently far from the sea as to possess a truly inland climate.

Even Taupo, the geographical centre, is but a hundred miles from the coast, and Rotorua is fifty miles nearer. Still, to a certain extent the whole plateau of the Thermal

District has an inland climate, is dryer, more bracing, and has greater contrasts of winter and summer than the coastal districts. The conditions are accentuated by the height of the plateau and by the dry, porous nature of the pumice soil.

Rotorua is situated on the shores of a lake roughly circular in form and 6 or 7 miles in diameter, at an altitude of nearly 1,000 feet, in a great basin of the hills, some 20 miles long and 10 broad. These hills, fern-clad on their cleared lower slopes, their summits covered with rapidly disappearing primeval forest, rise to a height of 1,000 or 1,500 feet above the level of the valley, and serve to shelter it to some extent from the full force of the winds.

The prevailing winds are the south-west and the north-east. The former is a cool and bracing wind coming from the high central plateau and snow-clad mountains of the Ruapehu group, and brings fine weather, bright, sunny, and tonic. It profoundly modifies the climate, and the weather is never sultry or oppressive while it is blowing. Frequently, however, it is somewhat boisterous and uncomfortably cold, and this constitutes what is perhaps the most serious climatic drawback to Rotorua.

The north-east to north wind, which comes next in importance, is the rainy wind. When it blows, Rotorua experiences its nearest approach to mugginess, and rain almost invariably follows. In fact, at these times the comparatively inland climate is exchanged for a moist sea one, the ocean to the north being only about 40 miles away.

In very fine, settled weather, however, there may be a daily alternation of light airs from the north-east and south-west, a true sea and land breeze, when the north-east wind no longer brings rain.

The altitude, however, is perhaps the most important local factor in modifying the climate. While not sufficiently high to serve as a contra-indication in atheromatous and other cases in which a high altitude is undesirable, it is quite sufficiently raised to render the climate distinctly

bracing except at certain seasons. The slightly rarefied air is more easily penetrated by the rays of heat and light, while radiation of heat and evaporation of moisture proceed more rapidly. As a consequence, there is a greater brilliancy of atmosphere than at places near the sea-level, the direct sunshine is hotter, the temperature in the shade much cooler, and there is a greater contrast of warm days and cool nights.

Another effect of the altitude of Rotorua is the comparative dryness of the atmosphere. This, while it is undoubtedly diminished by the presence of the lake and by the large amount of steam constantly arising from the hot springs, is sufficiently marked as a rule to prevent the air from feeling relaxing. Probably, however, the nature of the soil, the sparseness of the vegetation, and the configuration of the surrounding hills have all something to do with the local freedom from mists. It is quite common to see the whole circle of forest-clad hills full of tangled mists, while the broad valley beneath is perfectly clear.

Sunshine.—As in New Zealand generally, there is a very considerable amount of bright, hot sunshine, a matter not only of physical but of psychical importance to the invalid. As a consequence, a much more open-air life than in England is habitual.

Rainfall.—This is fairly heavy, but fortunately tends to come in short, sharp rain-squalls, when a large amount may be registered in a few minutes, or is massed into two or three days of heavy downpour, ushered in by a north-east wind. July and August are generally the wettest months.

The following tables give a general idea of the comparative rainfall and sunshine records of Rotorua and some British health resorts, the rain being the total fall in inches per annum, the sunshine the total hours per annum :

| | Rain. | Sun. |
|------------------------|-------|--------|
| Rotorua | 55·0 | 2303 |
| Hanmer | 41·12 | 2231 |
| Strathpeffer | 32·24 | 1188·3 |
| Scarborough | 27·27 | 1406·8 |

| | Rain. | Sun. |
|---------------------|-------|--------|
| Harrogate | 29·45 | 1501·8 |
| Bath | 30·47 | 1467·3 |
| Margate | 23·21 | 1539·7 |
| Hastings | 29·07 | 1782·9 |
| Worthing | 29·96 | 1845·4 |
| Jersey | 34·21 | 1926·8 |

The Season.—In so far as the treatment of invalids is concerned the season lasts all the year round, but the busiest time is from Christmas to the end of April. February is sometimes uncomfortably hot and close, more especially if, as is usual at this season, bush fires are raging in the hills of the back country, and should be avoided by those needing a bracing climate, while the late winter and early spring, July to September, are apt to be wet.

Frequently, however, the winter, especially the early winter, is remarkably fine and suitable for those invalids who need a tonic climate. The winters vary considerably, but in a good winter there may be day after day, and sometimes week after week, with a blue sky, a really hot sun, and a minimum of wind. With this there is a cold shade temperature and a fairly keen frost at night. Such conditions of keen, sparkling, exhilarating atmosphere recall that of an Alpine resort, though snow is unknown, and are particularly suitable for taking the tonic open-air hot baths. They will be especially appreciated by visitors from the hotter coastal districts of Australia, and if only the houses of Rotorua were built more warmly, a course of winter treatment would hold out many advantages over the usual summer one.

Sanitation.—The water supply is beyond reproach. A spring issuing from the foot of a mountain discharges practically direct into the main, and the water is not only clear and sparkling, but is free from any possible risk of contamination. As we have shown elsewhere (p. 27), owing to the insoluble nature of silicate rocks in cold water, the springs of siliceous districts are remarkably free from inorganic salts, and it can be asserted with confidence that

no more palatable and pure drinking water exists than at Rotorua.

There is an efficient water-carriage sewerage system, discharging through a septic tank well removed from all habitations. The average death-rate is about 10 per 1,000; but as this includes the hospital, in which cases are drawn from a large surrounding area, the true death-rate is somewhat lower.

Hospitals.—In addition to the usual general hospital, there is the Government *Sanatorium* or Mineral-water Hospital. This is reserved for patients requiring balneological treatment who are hardly able to stand the expense of boarding and treatment outside. This hospital, formerly of only thirty-five beds for men and women, has recently been considerably enlarged. It is under the charge of the Government Balneologist, and patients, in addition to receiving exactly the same treatment as private patients, have the advantage of skilled nursing, a very great desideratum in serious cases. *King George V Military Hospital* for physio-therapeutics was established during the war on Pukeroa hill, overlooking Ohinemutu and the lake. Here, under ideal natural surroundings, several thousand wounded and invalided soldiers have been treated with baths, massage, electricity, sunshine, and fresh air.

Accommodation.—There are two hotels in Rotorua proper and one each at Ohinemutu and Whakarewarewa. In addition there are some thirty to forty boarding-houses, some of which accommodate considerably more than a hundred guests, so that, under normal conditions, there is little danger of not finding a bed: at Christmas, however, and on special occasions, such as fêtes and tournaments, it is not advisable to rely on this.

Amusements.—Visitors accustomed to the casinos and bands of the continental spas must not look for them in Rotorua. There are, however, many compensations. There are, of course, golf links, and the public gardens, in which stand the baths, are not only beautiful in themselves, but



FIG. 37.—A GIANT AZALEA IN FULL BLOOM IN THE SANATORIUM GARDENS, ROTORUA.
Flowers bloom in magnificent profusion in spite of the fact, or possibly because of the fact, that their petals are often wet with the spray and sulphurous vapours of boiling springs, and that the ground is warm a foot or two beneath the surface.



FIG. 38.—FLY-FISHING AT OKERE, JUST ABOVE THE FALLS, A FAVOURITE SPOT FOR TROUT.

they offer opportunities for games, such as bowls, croquet, and tennis, which many a famous European spa might envy. It may interest the visitor to learn that this magnificent garden, with its wealth of lawns, flowers, and shrubs, was laid out in a howling wilderness of sulphur beds and pumice. Practically every spadeful of soil was carted on to the site, and as the subsoil is hot, the gardens constitute a huge forcing-ground for plants. Here and there a boiling spring serves to remind one that the smiling garden



FIG. 39.—WAR CANOE, HOLLOWED FROM A SINGLE TREE-TRUNK: LAKE ROTORUA.

is an exotic, and on rainy days steam and strong whiffs of sulphur forcibly do so.

Hydrothermal phenomena—geysers, boiling springs, and “mud pools”—more than compensate the ordinary visitor for the loss of casinos.

Then, to be visited close at hand, there are the interesting and picturesque Maori villages perched precariously on the very brink of a medieval Hades; launch picnics on Lake Rotorua and still more beautiful Roto-iti, trolling for trout for the uninitiated and fly-fishing for the expert, and numerous trips by motor or coach to spots beautiful or hair-raising. In general interest of outdoor surroundings there are indeed few spas which can rival Rotorua.

Cases Suitable for Treatment.—All those cases vaguely classed as “rheumatic” or “gouty,” and more especially those requiring a somewhat tonic line of treatment; cases of sciatica, lumbago, and fibrositis; sub-acute and chronic neuritis; cases of quiescent organic central nerve lesions requiring re-educative exercises; stiff joints and wasted muscles from traumatic or other causes—in fact, practically all cases requiring physical treatment; neurasthenics; cases of high blood-pressure; gouty glycosurics; cases of chronic skin disease.

The Baths.—There are two distinct types of bathing establishments, the Old Baths and the New. Each has certain peculiar advantages and certain drawbacks, but combined they form an establishment almost unique.

The *New* or *Main Baths* are housed in one large building erected in 1908 in the midst of the gardens. Constructed on the homely model of the old English half-timbered house, but with pumice-concrete substituted for lath and plaster, and native timber in place of oak, the building is in picturesque harmony with its garden surroundings, and the view from its upper windows is magnificent. Here are housed all the usual baths and appliances that one expects to find in a first-class spa in Europe; comfortably fitted bath-rooms and dressing-rooms, public baths, Aix massage baths, a well-equipped massage and electrical department, a “pump-room,” consulting-room, and waiting-rooms, the whole run under the strictest medical supervision. In the basement are the mud baths, supplied by the volcanic mud from local hot mud springs.

In this building one may receive exactly the same treatments as at, say, Buxton or Harrogate, with the difference that, whatever water is ordered—and some are quite unfamiliar in Europe—it has to be cooled very materially before use. No water has to be heated, and this is a very distinct advantage.

In these baths the waters from the different springs are led in pipes to their destination, in the case of the acid



FIG. 40.—THE MAIN BATHS, ROTORUA.

The lawns in front are laid out for tennis, croquet, and bowls

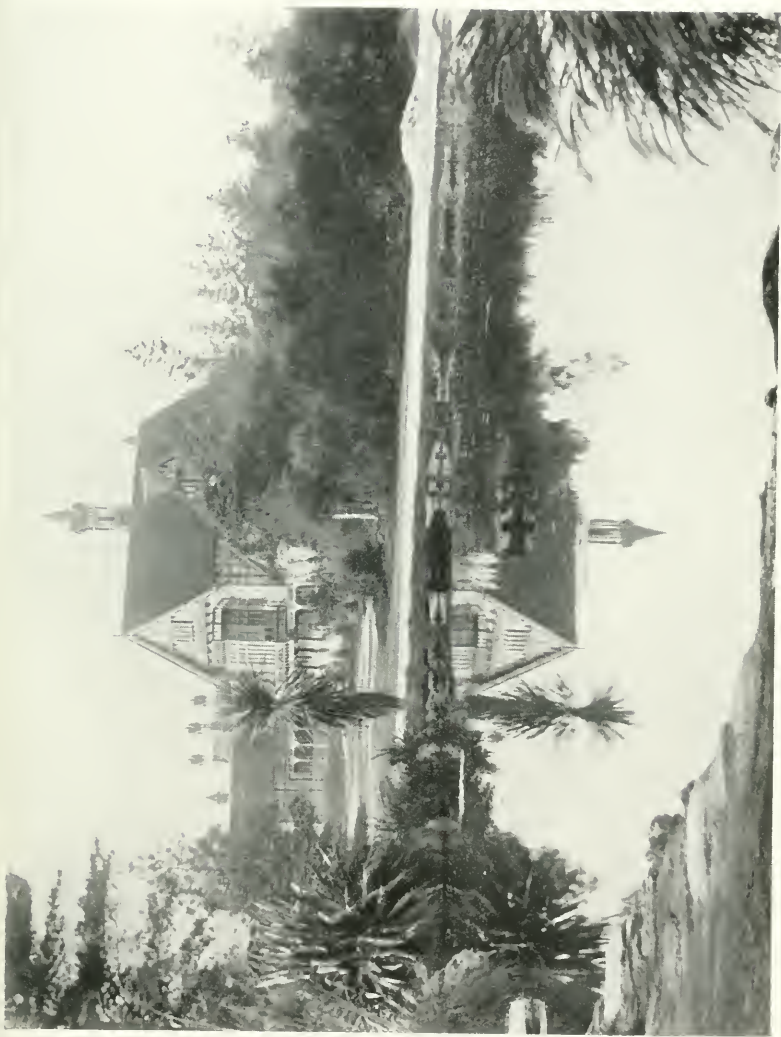


FIG. 41.—THE BATHS, ROTORUA, FROM A CORNER OF THE GARDENS.

Priest waters, in lead-lined pipes, and baths can be given at any prescribed temperature, with the accompaniment of douches, and with a minimum of fumes.

The *Old* baths consist of scattered groups of buildings, for the most part erected over the actual springs. They are at present of timber, and, it must be confessed, somewhat dilapidated and uninviting of appearance. Outward appearance must, however, be disregarded, for some of these baths are invaluable. They are the Pavilion, Duchess, Blue, and Postmaster baths.

The Pavilion Baths house in somewhat primitive fashion the old Priest Baths, the public and private Rachel Baths, and the Ladies' Swimming-bath.

The Old Priest Baths.—These are wooden piscinæ built over the actual springs, so that the bather's feet rest on the natural pumice floor, through which well the waters and the accompanying gases. They are surrounded by rough dressing-boxes, and supplied with overhead douches of Rachel water, to wash off the acid as well as to act as ordinary douches, and with cold showers. To permit of the free escape of all gases, the baths are only partially roofed over, so that they are practically open-air baths.

The Rachel Baths.—These are numerous private simple immersion baths and two Public Rachel Baths, the latter shallow concrete pools in which the water is maintained at 102° F.

The Ladies' Swimming-bath is supplied by the Rachel Spring. For safety made rather shallow, it is open to the sky, and, with its silky soft water, is a luxury in the true sense of that much-overworked word.

The Duchess Bath is a similar swimming-bath for men, but roofed in, and kept at a slightly higher temperature (98° F.) than the other swimming-baths, so that, while it is more useful for many therapeutic purposes, it is also distinctly relaxing as a swimming-bath.

The Blue Bath is a larger completely open-air swimming-bath reserved for men. It is supplied by the Malfroy geysers with a water closely resembling the Rachel, and is

kept at 94° F. From its lower temperature and open-air character it is less relaxing than the Duchess.

In the same building are the *Vapour Baths* (vide infra).

The Postmaster Baths are situated on the lake shore some half-mile away. Built on the model of the Old Priest baths over the actual springs, and, on account of the potent nature of the fumes, perforce entirely open to the sky, these baths are the strongest, most efficacious, and at the same time most risky of the baths of Rotorua.

The Spout Baths at Whakarewarewa are really a series of hot waterfalls rendered possible by the stupendous quantity of mineral water available from the overflow of a large boiling lake. The water, cooled in shallow pools, is led to a number of private baths, each of which has a controlled "spout," with about eight feet fall, and is fitted up with cold showers and dressing-boxes. The water somewhat resembles the Rachel, but is harsher, and at the same time more sulphurous, and this crude but very efficacious douche is of great value in such conditions as lumbago and chronic arthritis of the shoulder joints.

Natural Baths.—There is quite a number of "natural baths," large rocky pools for the most part, filled with hot water of varying temperature and constitution, either fed by the overflow of neighbouring springs or by springs arising through their floors. Some of these springs have considerable local fame, such as the "Lobster," the "Painkiller," etc., and there is no doubt whatever about their efficacy. At the same time, owing to their uncertain depths and temperatures, to the presence of gases, and to the absence of an attendant, these baths are excessively dangerous, and visitors are warned to let them severely alone. They are most fascinating and tempting, but are responsible for many sad tragedies. In addition there are numberless baths used by the Maori. Many a humble whare has alongside an open-air bath that a millionaire might well envy, and in the tea-tree scrub are hidden sequestered baths where family parties spend many happy hours with a "korero"¹ and a pipe.

¹ Chat.



FIG. 42.—THE FORESHORE OF LAKE ROTORUA AT OHINEMUTU.

In the foreground is a primitive native bath; on the hill in the background is a corner of King George V Hospital, where so many New Zealand soldiers were treated with baths, massage, and electricity during the War. One or two surviving Maori wharers, not yet supplanted by European shanties or more elaborate cottages, can be seen in the middle of the picture.



FIG. 43.—A MAORI WOMAN COOKING IN A STEAM-HOLE.

An old perforated packing-case is sunk in the ground : this is covered with a dilapidated sack, and the food, placed in flax bags, is cooked by natural steam.



FIG. 44. A NATURAL AND ECONOMICAL SUBSTITUTE FOR THE KITCHEN RANGE.



FIG. 45.—A HOT "LAKE," GREEN TO THE WATER'S EDGE: OHINEMUTU.



FIG. 46.—A MAORI MOTHER AND CHILD.



FIG. 47.—A MAORI LAUNDRY.
Washing clothes in a stream of hot mineral water at Ohinemutu.



FIG. 48.—WEAVING A FLAX MAT.
Such mats are used in the whares in lieu of carpets.



FIG. 49.—HIONGI, A MAORI GREETING.

"Rubbing noses" is a misnomer; the noses are rather pressed gently side by side.



FIG. 50.—A POI DANCE—MAORI WOMEN.



FIG. 51.—A FIGURE OF THE POI DANCE.

Balls of flax, suspended from a string of the same material, are used to accentuate the rhythm of the figure.



FIG. 52.—ANOTHER FIGURE OF THE POI DANCE.

In the background the celebrated old meeting-house Tama-te-kapua, Ohinemutu, unhappily defaced by European "improvements."



FIG. 53.—A HAKA, DANCED BY MAORI WARRIORS: WHAKAREWAREWA.



FIG. 54.—A FIGURE IN THE HAKA.



FIG. 55.—ANOTHER FIGURE IN THE HAKA.

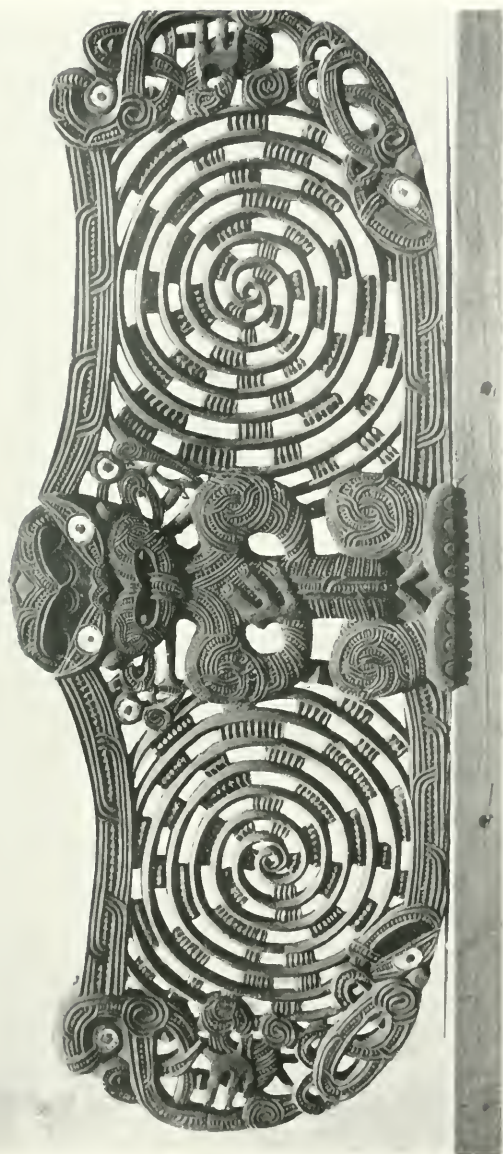


FIG. 56.—A FINE EXAMPLE OF MAORI WOOD-CARVING.

THE MINERAL WATERS

The mineral waters of Rotorua, while of endless variety as regards minor differences of analysis, are of two main types, the *alkaline* and the *acid*, and it is to the latter that Rotorua owes its pre-eminence as a spa, and as the spa more especially for *baths*. In this direction it claims a foremost position among the health resorts of the world, though in the matter of drinking-waters it is comparatively poor.

Alkaline Siliceous Sulphur Waters. — Waters containing sodium sulphide or, sulphuretted hydrogen are common enough in Europe, and indeed the world over, but highly siliceous waters are found only in volcanic springs of high temperature. The reason of this we have already seen,¹ the silicates being readily soluble in water at high temperatures, especially in the presence of alkalies,² but very insoluble in cold water. Siliceous waters are characteristic, therefore, of geyser regions, and are found in New Zealand throughout the Thermal District, and in the geyser districts of Iceland, of the Yellowstone, and of California.

As we noted in discussing the origin of the waters of Rotorua,³ all the waters of deep origin are alkaline, and all contain sulphides. The principal ingredients of these waters, then, are the chloride, sulphide, silicate, and bicarbonate of sodium, with smaller amounts of varying salts such as ferrous bicarbonate and sodium borate, and very variable amounts of carbonic acid and sulphuretted hydrogen gases. They are characterized by their very high temperature (180° F. to 212° F.); perfect clearness, and soft emollient feel.

Seen in bulk in a perfectly fresh condition they present every gradation of tone from almost colourless to a clear and beautiful blue, the colour being due to ferrous salts and silicates. Under certain conditions, for instance storage and free exposure to the atmosphere, oxidation causes a cloudiness of the water, and a fine deposit of silica collects, while the sodium sulphide combines with

¹ See page 27.

² See page 28.

³ See pages 28-30.

the atmospheric carbonic acid to form sodium carbonate, and the sulphur is liberated partly as sulphuretted hydrogen and partly as a flocculent precipitate.

The number of these springs is very literally uncounted; and though many of them have been analysed and show small differences, chemical, physical, and therapeutical, yet it will suffice if we take one spring as a type.

The Rachel Spring.—The most famous of these springs, although by no means the largest, is the Rachel, which constitutes the main supply¹ of alkaline water to the baths. The spring at one time may have been a geyser, in any case it overflowed a surrounding area of several acres and covered it with a firm stratum of silica. The shaft of the spring, some 15 or 20 feet in diameter, descends fairly vertically and has been sounded to 180 feet. Its walls are lined with geyserite, and the crystal-clear spring is of a deep blue. The surface temperature of the water varies from 185° F. to 200° F. according to the rapidity with which it is being drawn off, and occasionally it boils energetically. The water, which has a soft silky feel due to the silicates, and a somewhat nauseous taste due to sodium sulphide, is led by iron pipes—which, by the way, tend rapidly to be occluded by silication—to the baths, where it is used both for bathing and drinking purposes.

ANALYSIS OF RACHEL WATER (1912)

| | Grains per gallon. |
|-------------------------------|--------------------|
| Sodium chloride | 65.87 |
| Sodium sulphide | 10.27 |
| Sodium silicate | 23.78 |
| Sodium bicarbonate | 13.47 |
| Sodium sulphate | 1.50 |
| Sodium borate | 1.85 |
| Potassium chloride | 1.26 |
| Lithium chloride | 0.42 |
| Cæsium chloride | trace |
| Calcium bicarbonate | 0.41 |
| Ferrous bicarbonate | 0.01 |
| Carbon dioxide | 9.17 |
| | 128.01 |

Temperature 194° to 200° F.

¹ The amount used from this particular source varies within very wide limits, but would average about 100,000 gallons a day.

The most important therapeutic ingredients of this water are the sodium silicate and sulphide: the borate and the lithium and iron salts are present in such small amounts as to be only of minor importance.

Sodium Silicate, Internal Use.—So little is known of the action of silicates that for a long time I felt some hesitation about using internally so highly siliceous a water as the Rachel, not realizing the important part played by silicon as a constituent of the body.¹ There was also, in view of the extensive deposits of silica from the water, a not unnatural prejudice against it locally. For some years, however, I made an ever-increasing use of it, and never could discover any ill effects that could reasonably be attributed to the silicate. Also, because it is hard to distinguish the individual effects of the salts of so complex a body as Rachel water, I could never satisfy myself as to the part played by the silicate. The water was useful in a large number of cases, and that was all that could be said. Felix² was one of the first observers to point out the antiseptic properties of the alkaline silicates. He showed also³ the power of a mineral water containing such silicates (Sail les Bains, 9·1 grains per gallon) to dissolve uric acid in a test tube. Such an experiment *in vitro* is, of course, very inconclusive, as the conditions in which the silicate exist in the blood after absorption may be wholly different. That they are so absorbed is shown by the experiments of Zikgraf,⁴ who gave 1 gramme per diem of sodium silicate by the mouth, and found that the drug excreted in the urine. In a later communication⁵ he draws attention to the beneficial results in pulmonary tuberculosis of drinking the waters of Glashagen which contain 4 mg. of meta-silicate of sodium in 100

¹ Cf. footnote, p. 27.

² *Gazette des Eaux*, March 19, 1898 (quoted by Weber).

³ *Annales d'Hydrologie*, March 1898.

⁴ *Beitr. z. Klin. de Tuberkul.*, 1906, Bd. v, Hft 4.

⁵ *Centr. f. inn. Med.*, May 16, 1908 (quoted *Med. Annual*, 1909).

grammes of water.¹ Pascault² gave teaspoonful doses of a solution of sodium silicate of a strength of 172 grammes per litre as a gastric sedative and anti-fermentative in gastric flatulence and pain, and in cases of intestinal toxæmia. Sodium silicate has a remarkable power of arresting the fermentation of organic matter, and the beneficial effect of Rachel water in many cases of dyspepsia and auto-intoxication, and consequent goutiness, may well be due to the silicate.

Scheffer³ gave sodium silicate in arterio-sclerosis, using an aqueous solution of 1 in 18, and a dose of two or three tablespoonfuls daily in milk, water, or wine, and a specific action has been claimed for the drug in the treatment of adenoma.⁴

Sodium Silicate, External Use.—Externally we are on safe ground. The bland, soothing, antiseptic action of sodium silicate is invaluable in the treatment of some skin diseases, and is also probably in part responsible for the rapid healing of many varicose and other ulcers in patients taking the baths.⁵ In the form of the Plombières douche, it, taken in connexion with the borate, constitutes for this purpose

¹ He found a diminution of the leucocyte count in the peripheral blood, with an increased proportion of multinuclears, which, though this is a doubtful inference, may mean that the blood is more resistant and better able to deal with infectious agents. It is suggested in explanation of the more rapid healing of tuberculous cavities under the administration of silicates, that, as silicates constitute an important element in connective tissues, they promote the nourishment of that tissue in the lungs. If this is so they would be contra-indicated in chronic arthritis with a tendency to adhesions.

² *Bull. Gen. de Ther.*, July 30, 1907.

³ *Med. Press*, September 30, 1908. Silicates absorbed into the blood have a decalcifying effect on the body generally. In this connexion compare the advice of Sir James Barr, who, in "rheumatism," gives oatmeal porridge for the decalcifying effects of its contained silicates.

⁴ Percy Wilde, *Med. Annual*, 1912.

⁵ Compare Felix, *Gazette des Eaux*, May 19, 1908. Also the Rachel water has been extensively used in the Rotorua Hospital as a local bath in septic wounds, with most excellent results in spite of its hypo-tonicity. Compare the silicate treatment of cancer by Zeller (*Muench. Med. Woch.*, August 20, 1912; and by Czerny, *ibid.*).

an ideal bland antiseptic medium. Mechanically, also, it is of great assistance in the Aix massage douche.

Deleterious Effects of Silicates.—While there is no evidence of the mechanical deposition of silica in the body in the same manner in which it is so freely deposited in pipes conveying mineral water, experiment has shown¹ that large doses of silicon administered over a considerable period cause uniform symptoms of poisoning of the nervous system, such as headache, dizziness, and tremor. Rashes appear on the skin, and symptoms of intestinal irritation are set up.

Sodium Sulphide.—Authorities differ as to the therapeutic value of the various sulphides. Some, while admitting the utility of sodium sulphide, deny any virtue to hydrogen sulphide; others affirm the potency of hydrogen sulphide, and Kisch² pointed out that sulphuretted hydrogen affords a combination that permits the introduction into the body of sulphur in the finest conceivable division.

Analysis of mineral waters, unless the results are shown in terms of ions, is at best somewhat of a compromise, and the exact grouping of molecules permits of the personal equation of the analyst. An older analysis of the Rachel water showed the sulphide entirely as sulphuretted hydrogen, but that made in 1912, of water carefully collected and examined as soon as possible after collection, returns the sulphide as the sodium salt.

As we have noted elsewhere, this salt decomposes rapidly on exposure of mineral water to the atmosphere. Carbonic acid combines with the sodium to form the carbonate, while the liberated sulphur is in part precipitated and in part combines with the hydrogen of the water to form hydrogen sulphide. Coincidentally there is with these changes, as might be anticipated, an alteration in the electrical conductivity of the water, as I have shown in the case of the Rachel water (page 76).

Although the scientific evidence of the pharmacological

¹ *Deut. Med. Woch.*, No. 38, 1903.

² *System of Physiologic Therap.* (Cohen), London, 1902.

value of the sulphides is meagre,¹ the results of world-wide clinical experience of sulphur waters certainly point to their value in arthritic diseases. It is claimed that they stimulate the secretion of bile and also have a selective or intensive action of the metabolism of tissues affected by gout, so that, while their graduated use is beneficial, their incautious use may cause an exacerbation of symptoms which may result in an attack of acute gout.

In the presence of alkaline salts sulphur is thought capable of acting as an oxygen carrier, thereby increasing the intramolecular oxidation of albumin.

It is probable that there is a tendency for the sulphur to combine with the iron of hæmoglobin in the portal circulation, and so to hasten the destruction of effete red blood corpuscles. While in plethoric individuals this may possibly be desirable, in anæmic patients it is obviously an action to be avoided.

The action of sulphur waters on the bowel would seem to depend more upon the accompanying salts than on the sulphur, and Rachel water is certainly not a purgative for most persons.

On the whole, indeed, sulphur water *per se* appears to have very little purgative effect, but is said² to have an antiseptic action on the bowel, and therefore to be beneficial in auto-intoxication. This action would in Rachel water be augmented by the presence of the borate and silicate of sodium. The sulphide is absorbed from the digestive tract and rapidly diffused through the tissues, to be eliminated by the skin, kidneys, and lungs. Hence,

¹ Experiments based on the pharmacological effects of sulphur waters do not as a rule differentiate between the action of the various and numerous ingredients of the water. Thus the very interesting and instructive investigations of Dr. David Brown (*Proc. Roy. Soc. Med.*, May 1911) show that the Harrogate "strong sulphur water" used internally was diuretic, and increased nitrogenous excretion and that of endogenous and exogenous uric acid, but the part played by sulphur in this remains uncertain.

² R. W. Wild, "The action and uses of Sulphur and certain of its Compounds as Intestinal Antiseptics," *Proc Roy. Soc. Med.*, November 1910.

sulphur waters are recommended in furunculosis, acne, and some forms of eczema.

At Aachen, where the sulphur water, in conjunction with mercury, is used so extensively in the treatment of syphilis, it is believed that it brings out the symptoms of latent, and to that extent dangerous, syphilis. Mercury is supposed to be stored up in the tissues as an albuminate, the sulphur hastens albuminous katabolism, and thereby the excretion of mercury, and the latent symptoms become evident. There appears also to be little doubt that the internal administration of sulphur water tends to diminish the toxicity of mercury. Some patients unable to take even small doses of mercury without symptoms of mercurialism can take this drug in conjunction with sulphur without any ill effects.¹

Sulphur waters are supposed to have a specific action in chronic lead poisoning, and, in view of the modifying action of sulphur on that of mercury, it is possible by analogy that such may be the case. It is at least as possible, however, that the increased metabolism set up by spa treatment is the real agent. A similar specific action is claimed for non-sulphurous waters.

¹ In the *B.M.J.*, January 31, 1920, is an interesting note by Capt. E. Irving which may throw fresh light not only on the use of sulphur waters in mercurial poisoning, but possibly also in lead poisoning. Acting on Prof. Gaucher's theory, he gave teaspoonful doses of sublimed sulphur nightly by the mouth in cases of mercurialism induced by the intramuscular injection of mercury. He found that not only was mercurialism prevented, but cases of already developed stomatitis rapidly cleared up. Prof. Gaucher's explanation of the action of sulphur waters in mercury poisoning is as follows. Mercury, on absorption into the system, becomes converted into a chlor-albuminate-peroxide of sodium and mercury. It is an irritating salt, and is not allowed to circulate freely, thereby causing stomatitis and other symptoms of irritation. By the action of sulphur, the irritating mercury salt is converted into a non-irritating mercury sulphide, which circulates freely in the system. The mercury sulphide is easily excreted, and is well tolerated.

The thought suggests itself that possibly lead sulphide may behave in similar fashion.

See also Dr. Morna Rawlins, "Venereal Diseases in Women," *B.M.J.*, August 7, 1920.

Toxic Effects.—The long-continued action of sulphides is depressant to the heart and to the nerve centres, and is believed to stimulate the katabolism of red corpuscles, and so cause anæmia.

Ferrous bicarbonate.—The therapeutic action of iron in such minute doses is perhaps doubtful. Possibly the presence of an easily decomposable iron salt would tend to minimize the katabolic effects of sulphides on the hæmoglobin in the intestinal capillaries. For the same reason, namely, of interaction between the iron salts and the sulphides, the beneficial effects of the iron in anæmia would be minimized.

Lithium chloride.—Here, again, the quantities present are so very small that it would be rash to attribute to them much action without further evidence. Some action, however, is by no means impossible (see remarks on pages 95, 119, and 233).

Sodium borate.—The recent discovery of this salt in Rachel water is very interesting, and may account for its occasional purgative effects. Fortunately the amount present is too small to have an irritative effect (see Borate Waters, pages 95 and 204).

Dosage.—The water is given in small doses, gradually increased to 8 or 10 ounces, three times a day on an empty stomach. It is essential that it should be fresh and hot from the spring. The degree of freshness can be measured by the temperature, as, after standing and cooling, decomposition of the sodium sulphide takes place and the water becomes insufferably nauseous. When fresh, however, nearly all patients rapidly get to tolerate it.

The caution is given that Rachel water, and indeed all hot sulphur waters, should be taken in small doses until tolerance is established, and should not be gulped down too hurriedly. Neglect of this precaution may lead to headache, palpitation, and troublesome flatulence.

Indications.—The water is used internally in cases of

gout in which it may be feared that the strong alkaline waters of Te Aroha may precipitate an attack ; in cases of *arthritis* due to or exacerbated by *intestinal toxæmia* ; and in certain *skin diseases* such as *acne*. It will be seen that, on the whole, this water is much more useful for external than for internal administration.

Use of Rachel Water.—While the Rachel water is limited in its usefulness internally, as a bath it is for many purposes an ideal medium. Owing to its peculiarly bland and silky feel it is particularly adapted for swimming-baths, immersion baths, and douches. *Swimming-baths* are of course not intended primarily for therapeutic use, but swimming or wading in hot water is really an invaluable aid in many arthritic cases, as, the weight of the body being removed, crippled patients can make voluntary movements of the limbs otherwise impossible, more especially as the warm water simultaneously relieves pain and makes the stiff joints more supple. The abduction of the hip joints and the movement of the shoulder joints in swimming are especially valuable.

Immersion baths.—All the effects elsewhere described ¹ of hot baths can be obtained by immersion in Rachel water. As a sedative bath at the indifferent temperature the bland silicated water is ideal, and in diseases of the skin, in which a soothing antiseptic application is required, Rachel water is most useful. Where for any purpose a stimulant is preferable, the more potent acid waters should be employed. It is also largely used as a vehicle for the electric current in the electric bath.

Douches.—It is, however, in douche form that this water is most useful, for here its physical properties render it an ideal agent. The sodium silicate and bicarbonate make the water bland and, in combination with the sebaceous secretion of the skin, almost slippery, so that for the combination of douche and massage known as *Aix douche* it is invaluable.

¹ Vide page 249.

In douche massage the force of the water (at Rotorua, about 30 lb. to the square inch) materially aids the masseur's fingers, and indeed constitutes a form of massage as it impinges on the skin. Also, by directing the stream on to certain selected areas, the reflex effects described on page 245 are set up, and these effects can be increased immensely by the use of the *Scotch douche* of alternating hot and cold water. When the relief of pain is more especially aimed at, or derivative effects on the circulation are desired, e.g. in cerebral or hepatic congestion, the *revulsive* douche is used. In this the skin correlated with the part affected is treated by the prolonged use of a very hot douche followed by the momentary application of a cold one, to be followed again if necessary by hot. The water is also in constant use as the *undercurrent douche* in immersion baths, being applied under the water by a hose at a higher temperature than the bath. Both the force and temperature can easily be modified by moving the nozzle nearer to or farther from the part treated. This is an invaluable agent in the treatment of sciatica.

Indications for Rachel Baths. — Immersion baths are indicated in most cases of *skin disease* that will stand baths at all, except, of course, acutely infective conditions such as ringworm. The immersion should be prolonged, and special precautions should be taken afterwards to protect the skin from undue drying. Obviously, facial cases are contra-indicated. Sub-thermal baths in *insomnia* and *irritable nervous states* are useful. Rachel baths may be given for all cases of *chronic arthritic diseases* in which the stronger acid baths are not well tolerated.

Douche massage is contra-indicated in most acute conditions, but is invaluable in almost all others for which balneological treatment is indicated, and especially in the treatment of *fibrositis* and of *adhesions* of all sorts, such as stiff joints at any stage below that of ankylosis, adherent tendons, after fractures, dislocations, and other injuries, wounds, and surgical operations.

Through its reflex effects it is invaluable in the treatment of *atonic conditions* of the viscera, and, partly through relieving these conditions, and partly by direct stimulation of the nervous system, it is one of our most efficacious weapons in fighting *neurasthenia*. By its profound stimulation of local circulation it promotes local metabolism, the absorption of exudates, and the regeneration of tissue.

Acid Sulphur Waters.—In violent contrast to the above are the acid sulphur waters. Except that they are highly siliceous, the alkaline sulphur waters resemble fairly closely the widely distributed sulphur waters of Europe: the acid sulphur waters would appear to be without any European prototype, the only waters approaching them being certain waters in Japan and in the United States.¹

The most strongly acid waters of New Zealand rise in volcanic White Island,² in the Bay of Plenty—waters far too corrosive to use; the next strongest at Taheke, 12 miles from Rotorua; the next in Whale Island, in the Bay of Plenty, then at Ohaewai; and next come the waters of Rotorua.

We have already discussed (page 30) the probable genesis of these waters from an alkaline stock of the Rachel type. The springs are neither so plentiful nor so hot as those of the alkaline waters, but the water is nevertheless in great abundance and is practically a subsoil water under a considerable area of Rotorua.

For all practical purposes only three groups of springs are utilized, the *Postmaster*, the *Old Priest*, and the *New Priest*, and a glance at the table of analyses on page 76 will show that these differ from one another in degree rather than in kind.

The New Priest spring bears a closer resemblance to the Postmaster than to the Old Priest, and in point of acidity occupies an intermediate position. None of these waters

¹ Amongst others the Iowa spring contains 409 grains of sulphuric acid to the gallon and the Oak Orchard springs of New York as much as 40 per cent. of its total contents.

² See page 198.

ANALYSES OF ACID WATERS

| | <i>Postmaster Spring</i> {Analysis 1906}. | <i>Old Priest Spring</i> {Analysis 1906}. | <i>New Priest Spring</i> {Analysis 1906}. |
|--------------------------------|--|--|--|
| | Grains per gallon. | Grains per gallon. | Grains per gallon. |
| Potassium chloride . | 2.00 | 0.94 | 2.68 |
| Sodium chloride . | 8.89 | 7.03 | 15.10 |
| Sodium sulphate . | 14.25 | 10.85 | 19.94 |
| Aluminium sulphate . | 15.60 | 9.60 | 12.38 |
| Ferrous sulphate . | 0.52 | 0.06 | 1.30 |
| Calcium sulphate . | 6.25 | 6.46 | 4.85 |
| Magnesium sulphate . | 1.91 | 1.68 | 0.60 |
| Silica | 15.10 | 12.10 | 22.82 |
| Sulphuric acid (free) . | 22.29 | 3.77 | 16.80 |
| Total solids . | 86.81 | 52.49 | 96.47 |
| Gases : free CO ₂ . | 28.84 | 40.00 | 4.31 |
| „ H ₂ S . | 13.09 | 5.00 | 1.80 |
| Total | 128.74 | 97.49 | 102.58 |
| Temperature | 98° F. to 120° F. | 98° F. to 108° F. | 130° F. to 160° F. |

are used for drinking, but all make baths which have certain valuable and unique qualities.

Electrical Conductivity.—As this may be taken as a measure of the number of free ions in a mineral water, its investigation is a matter of some importance.¹ In the following tables a column of water $\frac{3}{16}$ inch in diameter was used at a temperature of 68° F. Water from the town main was used for purposes of comparison, and a 50-volt current passed between platinum electrodes. The waters were tested when freshly collected, and again after storage. As the Rachel water had to be allowed to cool through more than 100° F. it was of course not quite strictly fresh.

| Water. | Distance between electrodes. | Fresh water, current in m.a. | Tested after four weeks' stagnation, current in m.a. |
|------------------------|------------------------------|------------------------------|--|
| Town main | $\frac{1}{2}$ in. | 1.5 | 1 |
| Rachel water | $\frac{1}{2}$ in. | 17.0 | 15 |
| Priest water | $\frac{1}{2}$ in. | 19.0 | 17 |

¹ The point of complete ionization in an electrolyte is reached when the solution contains the molecular weight of the dissolved substance in a cubic metre. Thus the molecular weight of NaCl being 58.35, a completely dissociated solution would contain 58.35 gram. NaCl per cub. metre.

New Priest Baths.—These are housed in the Main Baths, and consist of a number of private and several public baths. All are supplied with the modern accessories of undercurrent and other douches, and all the private baths with packs, douches, and so forth. The waters, as we have seen, are stronger than the Old Priest waters, but weaker than the Postmaster, and are purposely used as free from gases as possible. They owe their action therefore entirely to their heat and to their contained sulphuric acid, and this latter is sufficiently strong to cause an intense and long-continued redness of the skin of the bather. The public immersion baths, one for men and two reserved for women, are kept at fixed temperatures of from 101° to 104° F.

Old Priest Baths.—These call for special note. They are a series of rude piscinæ, in which the bather's feet rest on the natural pumice floor, through which the hot acid water wells. The temperature varies in different baths, and in the same bath from day to day, and is comparatively little under control, the limits generally ranging from about 85° F. to 105° F. In the hotter baths there is a certain admixture of clay from the substratum, and a considerable deposit of flocculent sulphur in the bath, so that they appear a good deal less inviting than they feel. The coldest bath is a thing apart, and has special valuable properties. It is crystal clear, greenish in hue, and through its waters there is a constant bubbling of gas, principally carbon dioxide.¹

Of special value in those numerous cases requiring a subthermal tonic bath, it has the invaluable merit of feeling much warmer than it really is. This is due to the fact that the indifferent temperature of carbonic acid gas is 75° F., while that of water is about 93° to 94° F. (cf. p. 248), and that the conducting power of gas is low. It is to this gas that the stimulating properties of the bath are largely due, though the public having christened it at some time the

¹ The percentage of the gases (Dr. Maclaurin, 1911) is: CO_2 , 84.5; H_2S , 6.5; N, 9.0.

"radium bath," the name has stuck and its potency is attributed to radium.¹

Postmaster Baths.—The *Postmaster* baths are situated on the lake shore some half-mile away. Open perforce to the air on account of the potent fumes, these baths are built, like the Priest Baths, over the actual springs, and the bather rests on the pumice floor. The waters, however, are very much more potent than those of the Priest, as unfortunately also are the fumes, and consequently the Postmaster constitutes at once the most valuable and the most dangerous of all the baths at Rotorua.

Three baths are reserved for men and three for women, their temperature varying from about 99° F. to 110° F., or even more. The latter and hottest bath approximates to the Japanese type, and is especially valuable for local treatment, e.g. of the legs.

The waters well up through the floors of these baths accompanied by a considerable amount of gas, principally carbonic acid and sulphuretted hydrogen. As a rule these gases are rapidly carried off into the open atmosphere, but in certain conditions, especially with a low barometer, they are very profuse, and bathing at such times should only be undertaken with great caution. Rash bathers, disregarding the injunctions of the attendant, are frequently overcome by the fumes, and have to be removed hastily from the bath. Unconsciousness, with stertorous breathing and clonic spasm, comes on with startling rapidity, but passes off after a few minutes' exposure to fresh air. There is some consequent nausea and headache of a transient nature, but otherwise little after-results are noticeable beyond a very decidedly increased susceptibility to the fumes, so that a bather, once gassed, should not attempt the bath again for several weeks. The bath can be used for full immersion or locally, and in two distinct ways: (1) a short immersion, a very high temperature, and a following cold shower, especially if followed up by a sun-bath, cause

¹ The radio-activity of the water and gas is shown at pages 90-92.

active hyperæmia (vide p. 249) and distinctly tonic effects ; (2) a longer immersion at a somewhat lower temperature, followed by a douche of warm alkaline sulphur water, is used where relief of pain and stiffness is the most urgent indication.

In local application it is possible to utilize both methods. Thus a limb may be immersed, say, twenty minutes to get the maximum passive hyperæmia of Bier, while the body as a whole is treated by the tonic first method of a short immersion.

Physiological Action of Priest and Postmaster Baths.—

The physiological action of the Priest and Postmaster baths, both of which contain nascent sulphuric acid and carbonic acid gas, is interesting.

On entering the subthermal Priest bath there is first a sensation of chilliness, which gradually becomes replaced by a glowing warmth, due to the stimulation of bubbles of carbonic acid which collect on the skin in a fine layer ; the skin becomes bright scarlet from *active* hyperæmia, and there is vigorous contraction of the cutaneous unstriped muscles. Thus, in the male bather, the contraction of the dartos may be so vigorous after a few minutes as to become painful. This stage closely resembles the reactive stage (page 244) of the cold bath, but is more lasting. Practically the effects of a Nauheim bath result—a stimulation of the peripheral circulation, of the “ skin heart ”—the dilute sulphuric acid replacing the brine.

If now the blood be examined, it will be found that there is the same increased blood-count in the cutaneous circulation that we have elsewhere noted after a cold bath (see page 244).

In the hot Priest bath and in the Postmaster bath the preliminary cold stage is of course absent, and stage two of the hot bath (page 253) of active hyperæmia is speedily reached, and is very definitely prolonged. This is a tonic stage, and shows the characteristic increased blood-count. After more prolonged immersion we get stage three, that

| Case. | Date. | Sex. | Disease. | Bath. | Temperature of bath, Fahrenheit. | Duration of immersion. | Blood-count immediately before bath. | Blood-count after the bath. | Time from end of bath to second count. | Remarks. |
|-------|----------|------|-------------------------------|------------|----------------------------------|------------------------|--------------------------------------|--------------------------------|--|---|
| 1. | 14/10/09 | F. | Rheumatoid Arthritis | New Priest | 104° | 15 min. | 3,960,000 | 4,800,000 | 30 min. | |
| | 15/10/09 | " | " | " | " | " | 4,100,000 | 4,250,000 | 60 min. | |
| | 16/10/09 | " | " | " | " | " | 4,240,000 | 4,800,000 | 30 min. | |
| | 22/10/09 | " | " | " | " | " | 4,180,000 | 5,000,000 | 10 min. | |
| 2. | 22/9/09 | " | " | " | " | " | 3,800,000 | 4,266,000 | 15 min. | |
| | 6/10/09 | " | " | " | " | " | 4,200,000 | 4,800,000 | " | |
| 3. | 6/10/10 | M. | " | " | " | " | 4,840,000 | 5,100,000 | " | |
| 4. | 5/1/10 | " | Pernicious Anæmia | " | " | 10 min. | 1,230,000 | 1,000,000 | 30 min. | Patient was also given arsenic and other drugs. Went downhill eventually, and died after pneumonia. |
| | 22/2/10 | " | " | " | " | " | 1,700,000 | 1,700,000 | " | |
| | 25/2/10 | " | " | " | " | " | 1,600,000 | 1,600,000 | " | |
| | 17/3/10 | " | " | " | " | " | 1,560,000 | 1,600,000 | " | |
| 5. | 15/3/09 | F. | Rheumatoid Arthritis | " | " | 15 min. | 4,860,000 | 4,900,000 | 10 min. | |
| | 23/3/09 | " | " | " | " | " | 5,100,000 | 5,900,000 | 60 min. | |
| | 30/3/09 | " | " | " | " | " | 5,150,000 | 5,300,000 | " | |
| | 3/4/09 | " | " | " | " | " | 5,600,000 | 5,200,000 | 30 min. | |
| 6. | 25/9/09 | M. | " | " | " | " | Red, 4,000,000 White, 7,814 | Red, 4,300,000 White, 8,750 | 15 min. | Later the patient nearly died from persistent hæmorrhage following tooth extraction. From this he never really rallied, and went downhill after leaving the Sanatorium. |
| | 28/9/09 | " | " | " | " | " | White, 7,814 | White, 11,874 | " | |
| | 4/10/09 | " | " | " | " | " | Red, 3,700,000 White, 8,437 | Red, 4,800,000 White, 9,437 | " | |
| | 13/10/09 | " | " | " | " | " | Red, 4,800,000 | Red, 5,600,000 | " | |
| | 28/10/09 | " | " | " | " | " | Red, 5,300,000 | Red, 5,600,000 | " | |
| 7. | 2/11/19 | " | " | " | " | " | Red, 5,400,000 | Red, 5,750,000 | " | |
| | 22/10/09 | " | Subacute Rheumatism | " | " | " | 5,400,000 | 5,600,000 | 30 min. | |
| | 29/10/10 | " | " | " | " | " | 5,600,000 | 5,670,000 | 10 min. | |
| 8. | 18/9/09 | F. | " | " | " | " | 4,100,000 | 4,800,000 | 30 min. | |
| 9. | 4/9/09 | M. | Arthritis of Spine. | " | " | " | 5,800,000 | 6,400,000 | 15 min. | |
| 10. | 11/7/09 | F. | Rheumatoid Arthritis | Rachel | 102° | 10 min. | 5,100,000 | 4,900,000 | " | |
| 11. | 22/5/10 | M. | Convalescent Acute Rheumatism | New Priest | 104° | " | 5,833,000 | 6,400,000 | " | Good skin reaction. |

| | 23/5/10 | M. | Convalescent Acute Rheumatism | New Priest | 104° | 10 min. | 5,525,000 | 5,560,000 | 15 min. | |
|-----|----------|----|-------------------------------|----------------------|------|---------|---|--|----------------|--|
| 12. | 2/6/10 | " | " | Plain water | " | " | 5,760,000 | 5,850,000 | " | Poor reaction, patient chilly. |
| | 16/6/10 | " | " | " | " | " | 6,650,000 | 6,550,000 | " | |
| | 16/6/10 | " | " | New Priest | " | " | 5,916,000 | 6,230,000 | " | |
| | 18/5/10 | F. | Sciatica | " | " | " | 3,900,000 | 4,550,000 | " | |
| | 25/5/10 | " | " | " | " | " | 3,760,000 | 4,183,000 | " | |
| 13. | 6/6/10 | " | " | Plain water | " | " | 4,383,000 | 4,683,000 | " | 20 min. |
| | 10/6/10 | " | " | " | " | " | 4,125,000 | 4,550,000 | " | |
| | 23/6/10 | " | Rheumatoid Arthritis | New Priest | " | " | 2,933,000 | 3,091,000 | " | |
| | 30/6/10 | " | " | " | " | " | 3,400,000 | 4,150,000 | " | |
| | 7/7/10 | " | " | Electric Priest Bath | 102° | " | 4,480,000 | 4,300,000 | " | |
| 14. | 13/7/10 | " | " | New Priest | 104° | " | 4,583,000 | 4,950,000 | " | 15 min. |
| | 14/2/10 | " | " | " | " | " | 4,850,000 | 5,350,000 | " | |
| 15. | 24/1/11 | M. | Convalescent Acute Rheumatism | " | " | " | 6,567,000 | 6,706,000 | " | |
| 16. | 31/1/11 | " | Neurasthenia | " | " | " | 4,271,400 | 4,614,000 | 20 min. | Patient chilly after bath, with poor reaction. Had leucocytosis after vaccine; also had a meal an hour and a half before the bath. |
| | 6/2/11 | " | " | " | " | 15 min. | Red, 5,200,000 White, 9,680 White, 13,750 | Red, 5,970,000 White, 11,250 White, 10,937 | 15 min. | |
| 18. | 3/2/11 | " | Gen. Arthritis | " | " | " | | | " | Patient chilly after bath, and poor reaction. |
| 19. | 9/2/11 | " | Sciatica | " | " | " | Red, 5,912,500 White, 9,375 | Red, 5,818,750 White, 11,875 | Im- mediate | Patient very moderately red in part of body immersed, face and ears blue and cold; poor reaction. |
| 20. | 13/2/11 | " | Herpes Zoster (healed) | Old Priest | 87° | 30 min. | Red, 7,000,000 | Red, 6,246,000 | | Patient reacted strongly: skin very red and sweating profusely. |
| 21. | 30/1/11 | " | Sciatica | New Priest | 104° | 15 min. | 4,320,000 | 5,920,000 | 15 min. | Comparatively little hyperaemia of skin after the bath. |
| 22. | 20/12/10 | " | Rheumatoid Arthritis | " | " | 10 min. | 6,493,000 | 6,684,000 | " | |
| 23. | 9/1/11 | " | Locomotor Ataxia | " | " | " | 5,479,000 | 5,560,000 | 20 min. | |

of relaxation, with relief of pain and stiffness, relaxation of muscle, *passive* hyperæmia, and diminishing blood-count.

The most essential and characteristic feature of these baths, however, is the stage of active hyperæmia. Superadded to the pain-relieving effects of a hot bath we have the tonic effects of a cold bath, and the stage of reaction, of comparatively short duration in the cold bath, is, in the hot acid one, comparatively prolonged.

Blood Count after Priest Baths.—As we have already seen, the reactive stage of a cold bath is accompanied by an increase both of red and of white corpuscles in the blood circulating in the skin. This effect is increased by any measure which increases the vigour of the reactive stage, such as salt in the water, douching, massage, or vigorous muscular exercise. It is more marked in young, healthy adults than in older or asthenic subjects, and may be held as a measure of the reactive power of the individual, and also of the benefit that he has obtained from the bath.

Noting the extreme cutaneous hyperæmia that results from a Priest bath and its comparatively lasting nature, I examined the blood in a number of patients at varying intervals after bathing. The results showed that, in most cases in which skin hyperæmia was marked, the blood-count was increased. From the experiments of Winternitz and others one would expect the increase to be most marked in the part of the body actually immersed, and to make the test more severe the blood was accordingly withdrawn from the lobe of the ear, a part not immersed. Also, as some doubt was at that time expressed about the efficacy of the New Priest baths which had only recently been introduced, the test was made in one of them. The bath selected was the Public Priest Bath, a large immersion bath kept at a temperature of 104° F. and capable of accommodating a dozen or more bathers. With so large a body of water, a constant temperature was more easily maintained and disturbing factors eliminated. The apparatus used was the Thoma-Zeiss chamber, with Hayem's fluid as the medium

for the red and 5 per cent. methylene-blue-acetic-acid for the white. To complete the table, hæmoglobin estimations should have been shown; but as these were unfortunately not made in the earlier cases of the series, it was felt better to omit them, as a limited number might be misleading. Only cases of a consecutive series were included, and no selection of cases was made beyond the fact that all were invalids. For purposes of comparison, one or two tests were made from other baths and temperatures, such as the Rachel bath at 102° F. and with plain water. It is noteworthy that some of the latter gave positive results. It will be observed that the majority of the patients were enfeebled rheumatoid cases with very poor reactive powers, so that the results recorded, while not always striking, were encouraging for such an asthenic class.

Comparative Value of the Old and New Acid Baths.—

As regards the baths supplied by Rachel water, there is practically no difference between the two establishments, except in point of equipment and of comfort: in regard to the Priest baths there is all the difference in the world. At the New baths the Priest water is stronger in acidity and freer from gases; its temperature can be regulated exactly, and it can be used in the form of undercurrent douches. All these points are extremely valuable and constitute these most useful baths, more especially for the relief of pain and stiffness. Unless, however, the time of immersion is short, they are not particularly tonic.

The Old Priest baths and the Postmaster have certain drawbacks which are inherent and cannot be altogether removed. Thus the temperature is only roughly under control, obnoxious gases are a constant source of trouble, there are no undercurrent douches, and, bathing in the actual spring, the bather does not get either privacy or water untouched by others.

There are, however, very great compensatory advantages. The waters of the Old Baths possess all that quality of "freshness" the importance of which is elsewhere

dwelt on,¹ and they contain free ionized carbonic acid gas. The bath, too, is taken in the open air, the dressing-boxes alone being under cover. These factors combined render these baths very much more *tonic* than the more sophisticated New Baths, and in some cases they are effectual in relieving pain and stiffness in which the other baths have failed. For these reasons they are to be preferred to the New Baths in all cases of debility, such, for instance, as of rheumatoid arthritis or of anæmia, bearing always in mind, however, that the risks connected with the inhalation of sulphuretted hydrogen are to be guarded against.

As a general rule, of course, the more debilitated the patient, the cooler should be the bath, and the tonic bath *par excellence* is the Old Priest bath known as the "Champagne" or "Radium" bath. When it can be used, that is for robust subjects only, the Postmaster bath is very much more effectual than the Priest, and for the treatment of chronic arthritis there is no bath anywhere which can surpass it, and probably none that can equal it.

Indications for the Use of Acid Waters.—The *Priest* bath is invaluable in all chronic arthritic conditions, in "lumbago" and other forms of *fibrositis*, in *sciatica*, *neuralgias*, and in all forms of pain and stiffness due to *traumatic adhesions*. The cooler effervescent bath is more especially indicated where a tonic effect is required, such as in *rheumatoid arthritis*, *toxic arthritis*, and some forms of *neurasthenia*; also in *anæmic* cases. For cases of *weak heart muscle* it acts as a mild Nauheim bath, but special supervision should be ordered in these cases as the bath is not properly equipped for this purpose.

The *Postmaster* bath is used in the same class of case as the hotter *Priest* baths, but is more efficacious. It is also invaluable as a depletive of congested internal organs, and in defective circulation not due to heart disease. In short applications it is an excellent general tonic measure.

Contra-indications. — Both these baths are contra-

¹ Page 230.

indicated in very feeble patients, in most heart cases, and in skin diseases. Many persons with apparently normal skins are unable to use these baths, especially the Postmaster, on account of the supervention of a very irritable and obstinate erythematous rash. In the same way a slight abrasion may develop into an intractable ulcer, reminding one, in its obstinate resistance to treatment, of a mild X-ray burn.

Elderly people with pronounced atheroma or sclerosis should avoid taking the hotter baths, and especially the Postmaster, and should take special precautions before entering the bath.¹ As compared with men, women show a curious intolerance of the Postmaster bath.

Vapour Baths.—The hot-vapour room, *Russian bath*, is used as a preliminary of the Aix massage douche. The patient, after a preliminary drink of water and a spray of hot Rachel water, sits for a few minutes in the vapour room (temperature from 110° F. to 120° F.). Here his temperature rapidly rises, thereby hastening metabolism, profuse perspiration is induced, and the tissues are relaxed in preparation for the masseur.

The *vapour cabinets* at the Blue bath are supplied with steam either from the Malfroy geysers or from a sulphur cavern² under the bath. In the former case the steam is impregnated with a large amount of sulphuretted hydrogen and a small amount of sulphurous acid, in the latter it is heavily laden with sulphurous acid. This latter gas is readily decomposed in contact with air and moisture, and

¹ Either by applying cold to the head before entering, and while in, the bath, or by pouring very hot water over the nape of the neck. In either case they should enter the bath gradually.

² This solfatara was unearthed when excavations were made for the swimming-bath. Of late years its action has been very erratic, probably due to leakage of the water from the swimming-bath into the sulphur cavern. As an example of the engineering difficulties encountered at Rotorua, it may be mentioned that, while this bath encountered a solfatara, the Duchess swimming-bath rests on a foundation of nearly boiling mud, and everywhere metal pipes are eaten through, and all paints with a lead foundation are impossible.

nascent sulphur is deposited in a fine layer over the body of the patient. The inside of the cabinet, and the flues conveying the vapour, are coated with beautiful flower-like crystals of sulphur, which may reach a length of two inches or more.

The bath results in an intense reddening of the skin, active hyperæmia as well as passive taking place, and a certain amount of sulphur apparently is absorbed by the unbroken skin, as is evidenced by the evolution of sulphides in the sweat for some days afterwards. Of course special precautions have to be taken to avoid the chance inhalation of any of the vapour, as it is intensely toxic.

The bath may also be used locally, one or more limbs being inserted into the cabinet as in the well-known Berthollet system.

Indications.—A vapour bath is given when it is desired to increase the action of the sweat glands. Thus, in the form of the Russian bath, it is given almost as a routine measure in arthritic cases to increase elimination of toxins; in obesity it is especially indicated.

The vapour cabinet at the Blue bath obviates the discomfort of inspiring a hot steamy atmosphere, and, if the sulphur dioxide vapour is used, there is considerable absorption of sulphur, so that the bath is specially indicated in gout, metallic poisoning, and syphilitic cases in which it is desired to promote the metabolism of mercury. In cases of acne it is sometimes used with great success, but its action is uncertain.

Locally it is extremely useful as an aid to overcoming adhesions in a stiff joint and for relief of pain.

The physiological action of these local baths is: increased local temperature with increased local metabolism; local passive hyperæmia, with increased phagocytic activity, effects which are now familiar through the teaching of Bier; and local active hyperæmia from the stimulation of sulphurous acid and nascent sulphur, with the regenerative effects of increased arterial supply.

Contra-indications.—The complete vapour bath is contra-indicated in febrile cases, cardiac weakness, and advanced arterio-sclerosis or renal disease.

Mud Baths.—The material used is the dried clay deposit collected from the hot mud springs of the district, liquefied and heated again by steam. The mud springs and mud volcanoes, which are common in the district, but especially numerous in the Arikikapakapa reserve, are caused, as we have already seen, by the passage of steam through the clay substratum which underlies the pumice and sand of the Rotorua basin.

The material, resembling fuller's earth, is homogeneous, free from grit, and, when dried and powdered, distinctly greasy to the feel. In the fresh state, in its pultaceous condition in the springs, it is highly acid. In composition it consists principally of silicates with a large admixture of free sulphur, and is somewhat radio-active. It will be observed that the mud baths of Rotorua are essentially different from the peat baths so much used in Europe, and closely resemble the "fango" baths of Italy, such as those of Acqui and Battaglia, or the mud baths of Dax.

The mud is used in two forms, either locally, when it is applied as a thick poultice, or in the full reclining bath with a consistency varying from pea-soup to thin gruel. The bath is followed by a circular needle douche of Rachel water, when the mud readily washes off,¹ and a hot pack.

The temperature can of course be varied at the discretion of the prescriber, but for the relief of pain and stiffness a temperature of 104° F. or 105° F. is desirable, while as a sedative measure in certain skin diseases a much lower temperature is generally used. Owing to the low conductivity of the medium, mud can be borne of a higher temperature than water, as a comparatively insulating layer of mud rapidly forms around the bather. The skin is quickly

¹ In skin diseases it is sometimes allowed to dry on.

reddened by the free acid and free sulphur present, and to this is added the demulcent effect of the bland siliceous material. The bath thus acts as an alterative to the skin, and has marked pain-relieving properties.

Indications.—For the relief of pain and stiffness in *gouty* and *rheumatic cases*, in which acid baths are found too irritating to the skin, or where purely sedative effects are desired, the mud baths are extremely useful. Personal idiosyncrasy, or perhaps some unrecognized peculiarity in the phase of the disease, would also appear to come in, for many patients experience immediate relief from a mud bath, while apparently identical cases do better with a Priest bath.

The mud, too, would appear to have a specific action in many skin cases, especially *psoriasis* and dry chronic *eczema*. Remembering the antiseptic properties of both sulphur and the silicates, and the bland physical properties of the latter, it is not surprising that the mud should form an ideal application.

ANALYSIS OF VOLCANIC MUD

- (i) Direct from hot spring.
(ii) Dried mud stored at baths.

| | (i) | (ii) |
|------------------------------------|--------|-------|
| Silica | 61.65 | 48.52 |
| Alumina | 21.84 | 28.45 |
| Iron oxide | 0.50 | 0.40 |
| Titanium dioxide | 0.40 | 0.40 |
| Lime | 0.30 | 0.40 |
| Magnesia | 0.20 | 0.23 |
| Alkalies | 0.50 | nil |
| Free sulphur | 0.85 | 0.08 |
| Sulphuric anhydride | 2.80 | 0.81 |
| Water and organic matter | 11.05 | 20.46 |
| | <hr/> | <hr/> |
| | 100.15 | 99.75 |

Also sample (i) contained :

| | |
|------------------|------------------|
| Gold | 0.5 gr. per ton. |
| Silver | 7.0 grs. „ „ |

For the sake of the comfort of the patient, the mud is generally washed off after a twenty minutes' immersion, but frequently it is left on to dry and form a protective coating.

In poultice form, as a "local mud bath," it is useful in applications to single joints, such as the knee.

Like other baths which cause an artificial pyrexia, it is sometimes used with great success in the treatment of *obesity*.

Contra-indications.—The bath is sedative and rather debilitating, and must be used with caution in patients already debilitated by disease, e.g. rheumatoid arthritis, or where there is a tendency to cardiac failure. Those suffering from palpitation in a hot bath, and they are many, should avoid covering the precordium in the bath,¹ and in the subsequent pack should have a cold compress over the heart. Like all other forms of bath treatment, it is, of course, an unsuitable medium for treating disease of the skin of the face.

Radio-activity of the Waters.—As is discussed elsewhere (page 233), it has been suggested that one of the possible factors in the efficacy of a mineral water, as distinguished from plain water, is radio-activity, or perhaps, as plain water may be at least as radio-active as mineral water, it would be more correct to put it that radio-activity may be one of the factors concerned in the quality of "freshness" in water. Whether that is so or not, certain it is that water that has lost its freshness has also lost the bulk of its radio-activity, unless it has been artificially activated.

The reason of this is manifest. We are dealing, not so much with a solution of radium, as of its short-lived descendant, the emanation, whose decay period is about five

¹ The action is partly due to pressure, but is mainly a skin reflex. Warmth quickens and weakens, cold slows and strengthens the pulse, when applied over the heart. A cold precordial compress acts like digitalis.

and a half days.¹ Whether or not the small amount of radio-activity present in mineral waters is therapeutically potent is a question which cannot yet be answered with any degree of confidence. Many clinical observers, including some well-known investigators, have maintained that it is; on the other hand, no less an authority than Professor Rutherford has said that "it seemed to him that proof was lacking that the beneficial effect of (mineral) waters was due to radium."

In regard to the mineral waters of Rotorua, one might naturally anticipate that the excessively high temperatures of most of the springs would conduce to a very rapid loss of emanation, and, as a matter of fact, it has been found that their average radio-activity is low, much lower than that of the cold springs of the same district. This fact would rather lead to the conclusion that radio-activity is not an essential, and probably not an important, constituent of the quality of "freshness."

An examination of a number of waters was made by Dr. Maclaurin in 1911, which showed that their radio-activity was low as compared with that of many well-known waters in other parts of the world. The results of his examination of the waters, volcanic mud, and sinter deposits is given below in tabular form.

The following tables show the activity as expressed in billionths of a gramme of radium per c.c.

TABLE I. RADIO-ACTIVITY OF GASES

| Source. | Location. | Temperature (Centigrade). | Activity. Grams $\times 10^{12}$ per c.c. |
|----------------------------|-----------|------------------------------|---|
| Old Priest Bath. . . . | Rotorua | — | 0.170 |
| Gas Spring in Lake Rotorua | " | — | 0.697 |
| Waitangi Spring | Roto-chu | — | 0.021 |

¹ For the influence of radio-activity on the suspension of colloids v. page 233.

TABLE II. RADIO-ACTIVITY OF WATERS

| Source. | Location. | Temperature (Centigrade). | Activity. |
|--|---------------|------------------------------|-----------|
| Rachel Spring ¹ . . . | Rotorua | 90° to 100° | 0·0920 |
| " " ² . . . | " | 90° to 100° | 0·0890 |
| Old Priest Bath ¹ . . . | " | 38° | 0·1310 |
| " " ² . . . | " | 38° | 0·1090 |
| Postmaster Bath ² . . . | " | 40° | 0·0100 |
| New Priest Spring ¹ . . . | " | 40° | 0·0320 |
| New Priest Spring (from tap in bath-house) . . . | " | 40° | 0·0250 |
| Malfroy Geyser . . . | " | 100° | 0·0015 |
| Boiling Lake—Spout Bath . | Whakarewarewa | 100° | 0·0160 |
| Hamurana ¹ (not mineral water) . . . | Rotorua | 11·5° | 0·3490 |
| Fairy Spring ¹ (not mineral water) . . . | " | 14° | 0·3090 |
| Waitangi Spring . . . | Roto-e-hu | 40° | 0·0110 |
| Champagne Pool ¹ . . . | Wai-o-tapu | 72° | 0·1470 |
| " " ¹ . . . | Wairakei | 100° | 0·0080 |
| " " ² . . . | " | 100° | 0·0100 |
| Great Wairakei Geyser ² . . | " | 100° | 0·0050 |
| Witch's Cauldron ² . . . | Taupo | 100° | 0·2040 |
| No. 2 Spring . . . | Te Aroha | 38° | 0·0260 |
| No. 6 " . . . | " | 35° | 0·0150 |
| No. 8 " . . . | " | 42° | 0·0100 |
| No. 15 " . . . | " | 50° | 0·0310 |
| No. 20 " . . . | " | 18° | 0·0560 |
| No. 22 " . . . | " | 21° | 0·1300 |

TABLE III. RADIO-ACTIVITY OF MUD USED IN MUD BATHS

| Source. | Location. | Temperature (Centigrade). | Activity. |
|-----------------------------|-----------|------------------------------|-----------|
| Mud from boiling spring . . | Rotorua | 100° | 0·091 |
| Mud in use in baths . . . | " | Cold | 0·185 |

It will be noted that the highest activity was found in the two cold fresh-water springs, and the next highest in the subthermal Priest bath and its gases. The mud in use at the baths showed a higher activity than that collected fresh from the spring. The former consists of the dry deposit collected from the margins of a boiling mud spring, artificially made pultaceous by steam. It is probable that

¹ Waters examined in the field.

² Waters examined on a subsequent investigation eight months later in the laboratory by a more sensitive electroscope of the Joly type.

this unexpected result was due to the chance selection of samples.

The waters, and also the sinters deposited round boiling springs and geysers, were then examined for their actual radium content, apart from emanation.

TABLE IV. RADIUM CONTENT OF WATERS

| Source. | Location. | Activity. |
|-------------------------------|------------|-----------|
| Rachel Spring | Rotorua | 0.0004 |
| Old Priest Bath | " | 0.0003 |
| Hamurana | " | nil |
| Waitangi | " | nil |
| Champagne Pool | Wai-o-tapu | 0.0002 |
| " " " " " " " " | Wairakei | 0.0003 |
| Great Wairakei Geyser | " | 0.0005 |
| Witch's Cauldron | Taupo | 0.0005 |
| No. 2 Spring | Te Aroha | 0.0009 |
| No. 6 " " " " " " " " | " | 0.0002 |
| No. 8 " " " " " " " " | " | 0.0001 |
| No. 15 " " " " " " " " | " | 0.0012 |
| No. 20 " " " " " " " " | " | 0.0005 |

Comparing this table with Table II, Dr. MacLaurin points out that only a very small part of the emanation found in any of the samples is due to radium contained by the waters.

Sinters.—It will be recalled that radio-activity was discovered in the calcareous and other deposits round some of the European springs before it was detected in the actual waters.

The same relative radium richness is found in the sinters, and is much greater than that of any of the corresponding springs from which the sinter was deposited.

TABLE V. RADIUM CONTENT OF SINTERS

| Source. | Location. | Radium, — ¹² Grams × 10 per gram. |
|------------------------------------|---------------|--|
| Rachel Spring. | Rotorua | 0.72 |
| Boiling Lake | Whakarewarewa | 1.03 |
| Waikite Geyser | " | 0.41 |
| Small Geyser | Waimangu | 1.55 |
| Champagne Pool | Wairakei | 0.46 |
| Prince of Wales' Feathers Geyser . | " | 0.91 |



CHAPTER VI (*Continued*)

THE SULPHUR SPAS

HANMER

WHAT Rotorua is to the North Island, Hanmer is to the South. While by no means the only hot springs in the South Island, those of Hanmer are the only ones of any magnitude at present easily accessible, and they have an especial importance in that they can be reached from the most populous centres of the South without, what is to many invalids often a serious drawback, the discomforts of a sea passage.

Access.—The principal route, and the only one practicable for invalids, is by train from Christchurch to Culverden, a distance of 69 miles, and thence 24 miles by the regular motor-car service to Hanmer.

Accommodation.—There are several boarding-houses and private hotels, some of which are very comfortable, while for hospital patients there is the Government Sanatorium. During the war a large hospital was built for the accommodation of wounded soldiers.

Season.—The baths are open all the year round, but the season is from October to May. The winter, however, holds out many attractions to those who need bracing up, and are yet not too invalided to endure the keen frosty air.

Climate.—Situated in an elevated plateau 1,220 feet above sea-level, rimmed round by high mountains, and shut off by the central mountainous backbone of the island from the moist west winds, Hanmer possesses in its climate a curative factor scarcely less valuable than its mineral

waters. The air is comparatively dry, absolutely pure, and has just that touch of keenness in it which exhilarates and lessens fatigue—in a word, is “bracing.” The prevailing wind is from the north-west, a fine-weather wind, but often rising to a gale between the months of September and December. The wettest months of the year are August and September, whilst the autumn months, and particularly May and June, are generally fine.

In the winter there are very many bright and brilliantly sunny days, with the snow-wrapped mountains sparkling in the sun, warm in the sheltered valley below, but with a keen frost at night.

The Springs.—A considerable number of springs arise within the Sanatorium grounds, though all appear to have a common origin. The temperature of these springs varies from 100° F. to 118° F., and the flow is, for New Zealand, comparatively small, about 40,000 gallons a day. From them there is a fairly copious evolution of carburetted hydrogen gas (methane) mingled with a little sulphuretted hydrogen. At one time the whole of this gas was collected and utilized for lighting and cooking purposes at the Sanatorium; now, however, none is drawn from the bathing-pools during the hours of their occupation, and the surplus gas escaping from the springs is alone utilized.

In 1912, to augment the supply of water, a bore was put down, and a very copious flow at 120° F. was obtained, thus enabling the activities of the spa to be increased.

The Waters.—The mineral waters were formerly classified as sulphuretted saline, but the analysis of 1912 showed the presence of hitherto unsuspected borates, and they are here classified also as borated waters (cf. page 203). They are used both for drinking and bathing purposes, but mainly for the latter.

In composition they are feebly saline and contain 2 grains of sodium sulphide to the gallon, with a little alkaline carbonate, so that their action is that of the alkaline saline and sulphur waters (cf. pages 67-72). They also contain a

little lithium. The amount is little more than half a grain to the gallon, but, as explained elsewhere (vide page 233), in ionized solution, such as fresh mineral water, one can by no means always judge the activity of a water by its gross chemical constitution. Very conflicting views are held as to the value of lithium. While some authorities regard it as a specific in gout, others aver that it is not only useless, but that it irritates the stomach and acts as a general depressant.¹

Luff² says: "The chief objection to the lithium salts is their greater toxicity and depressing action on the heart as compared with potassium salts. They consequently have to be given in such small doses that it is doubtful whether they possess any remedial effect." It will be noted that both these objections are overcome by its employment in an ionized mineral water, for the dose is too small to be irritant, but is at the same time more potent pharmacologically on account of its ionization.

There is, at any rate, evidence of its value when introduced through the skin by electrolysis, and it is highly recommended for this purpose in gout by Leduc and others. With lithium chloride at the anode, lithium is driven in, and the uric acid ion may be found in the electrode.

The sodium borate, however, is the most active ingredient of these waters. For a full discussion of the action of borated waters the reader is referred to page 204; suffice it here, that, while adding to the value of the waters in certain baths, the borates detract from them for drinking purposes, as taken in any quantity they act as gastro-intestinal irritants.

The waters therefore should be drunk in small doses only; up to about 6 ounces, and under medical supervision.

¹ Murrell, *Clin. Journal*, May 19, 1909; and Fenner, *Lancet*, December 19, 1908.

² Hutchinson and Collier's *Index of Treatment*.

ANALYSIS (1912)

| | Grains per gallon. |
|--|--------------------|
| Sodium chloride | 52.75 |
| Sodium borate | 17.57 |
| Sodium silicate | 3.86 |
| Sodium sulphide | 1.45 |
| Sodium bicarbonate | 2.71 |
| Potassium chloride | 0.17 |
| Lithium chloride | 0.47 |
| Ammonium chloride | 1.09 |
| Calcium bicarbonate | 1.50 |
| Ferrous bicarbonate | 0.02 |
| Total solids | 81.68 |
| Carbon dioxide (free) | 5.32 |
| Carburetted hydrogen, free effervescence. | |
| Temperature, 100° to 120° F. in different springs. | |

GASES FROM THE WATERS (1912-13)

| | Per cent. |
|--------------------------|-----------|
| Methane | 92.31 |
| Carbon dioxide | 0.06 |
| Oxygen | 0.50 |
| Nitrogen | 7.13 |
| | 100.00 |

Baths.—It will be seen from the foregoing that the waters of Hanmer are more suited for baths than for drinking purposes, and indeed their soft, bland, antiseptic nature makes them peculiarly fitted for this purpose, especially as prolonged immersion baths in certain skin diseases and as the Plombières douche (cf. p. 68).

As at Rotorua, the baths may be divided broadly into two classes, the natural and artificial, both with their own peculiar advantages and drawbacks.¹ The former are excavations over the site of actual springs, with concrete sides, a grated floor to allow of the free passage of mineral water and gases, and an awning overhead to protect from sun or rain. Such are the two "swimming-pools," one for men and one for women, oval concrete baths some

¹ For a discussion of the comparative merits of these two types of baths see page 83.



FIG. 58.—A BATH-HOUSE, HANMER.



FIG. 59.—QUEEN MARY'S HOSPITAL, HANMER.

30 feet long and $4\frac{1}{2}$ feet deep. These baths were formerly maintained by their springs at a temperature of from 90° F. to 97° F., and, though useful as subthermal baths and for recreative purposes, were too cool for most arthritic cases. The greatly increased amount of water now available from the bore, however, has enabled the installation of under-current douches at a high temperature, which have not only greatly increased the temperature of the baths, but have also increased the scope of their therapeutic potentialities.

In addition the gas which formerly was withdrawn from the pools is now allowed to bubble freely through the water; there is thus more stimulant action on the skin, and, on account of the lower indifferent temperature of gases as compared with that of water, the apparent temperature of the bath is increased. In the other type of baths the water is led from the springs in pipes in the usual way. In addition to several step-down baths of the Roman pattern there are some 22 ordinary shallow immersion baths. These are fitted with hot undercurrent douches and cold showers, are roomy and comfortable, and the temperature can of course be varied to suit the needs of the bather. Special baths and towels are reserved for patients suffering from disease of the skin.

Swimming-bath.—A very fine bath, originally erected as a cold fresh-water swimming-bath, has been converted into a tepid mineral-water bath. Apart from purposes of recreation, a warm swimming-bath affords invaluable exercise to many patients too crippled to walk but not too crippled to wade or even swim.

Massage and Electrical Department.—A system of douche-massage, a combination of the familiar Aix and Vichy types, closely resembling that in use at Rotorua, is available, with circular needle baths, hot vapour cabinets, packs, etc.

In the dry-massage department treatment is given under medical prescription only, and may be combined with the usual faradic and galvanic applications, or with electric baths.

Inhalation.—The present arrangements for inhaling the

vapours of the water are decidedly primitive, and consist merely of pipes leading from a reservoir over a hot spring into the open air. Patients seated above the reservoir can thus inhale the steam, which consists only of simple hot-water vapour and a slight admixture of the gases, the salts of the water of course not arising with the steam. Owing, however, to the minute subdivision of the water, this vapour penetrates far into the bronchial tubes, and is not arrested in the upper air-passages as it would be in an ordinary spray. It thus exercises a bland sedative action on the mucous membranes, and tends to liquefy the bronchial secretions.

Radio-activity.—No systematic examination has so far been made of the waters of Hanmer. A preliminary rough examination that I made in 1914 indicated that their activity was comparatively slight.

Hill-climbing.—A large proportion of those who resort to Hanmer come rather for rest and change than “to take the waters,” but those who are seriously taking a course of baths should observe some caution in the matter of over-strenuous exercise. In many cases, during either part or the whole of a course, rest is absolutely essential, and serves to counterbalance the fatigue induced by hot baths; but frequently, indeed in the majority of cases, a certain amount of exercise is highly beneficial. For those persons, otherwise in good health, who are merely suffering from the effects of too sedentary a life, the exercise may take the form of walks, of ordinary outdoor sports, or of mountain climbing, care being taken, of course, not to attempt too much at first; but for those suffering from actual organic disease, exercise, while equally beneficial, must be much more carefully graduated. Many cases of enfeebled heart, of anæmia, of obesity, and of constipation will benefit by a judicious course of hill climbing, such, for instance, as is afforded by the slopes of Conical Hill, which seems to have been constructed by nature expressly for this purpose; but all patients with organic disease should avoid this method except under the strictest medical supervision.

Cases Suitable for Treatment.—The baths are indicated in the usual *chronic arthritic diseases*, and in the local manifestations of these diseases, such as *sciatica*, *lumbago*, and certain forms of *neuralgia* and *neuritis*. For cases specially requiring the more elaborate forms of treatment, while douche-massage electrical treatment and so forth may be obtained, the equipment is much less complete than that at Rotorua, and all cases of disease of the central nervous system requiring special re-educative and co-ordinating exercises, and those of heart weakness needing resistance exercises, should, for the present at any rate, be sent preferably to Rotorua. Patients suffering from true *rheumatoid arthritis* (cf. p. 140) are likely to receive benefit from the combination of the bracing climate and balneological treatment, and many do better here than at Rotorua. The same remark applies to many cases of *anæmia*, *nervous exhaustion*, and *insomnia*. In regard to insomnia, it is obvious that the cause must first be removed, but that done, the habit remains, and a sojourn at a spa of moderate altitude, combined with a course of moderately warm baths, may be availing. Certain *digestive troubles*, such, for instance, as atonic dyspepsia and constipation, will do well with a combination of massage-douche, electrical treatment, exercises, and possibly small doses of the water by the mouth. Here, again, while the bracing climate and the treatment assist the cure and stimulate the appetite, it must be remembered that the increased appetite may have to be restrained at first in the dyspeptic, while the diet of course must be carefully regulated in quality.

Certain *skin diseases*, notably chronic eczema and mild cases of psoriasis, are usually benefited by prolonged immersion baths. It is possible that the mild antiseptic action of the sodium borate may be of value in such cases.

Convalescents from acute diseases will find the pure, bracing upland air markedly invigorating, but must be careful to avoid too hot or too prolonged baths. *Stiff joints* and *muscles* after injury or operation will be rendered more

supple by a course of baths, especially douche-massage. In regard to chronic lead-poisoning and the secondary lesions ensuing therefrom a good deal of benefit is likely to result from treatment, but this, I take it, is due to spa treatment as such rather than to any specific action of the waters.

As already noted, borax would appear to possess some specific action in the reduction of weight in obesity and in improving diabetics, but the toxic effect of the salt when pushed to the necessary degree would appear to make the treatment somewhat risky.

Contra-indications.—It must be borne in mind that Hanmer is, for most part of the year, a quiet and restful resort rather than a gay centre, and should not be recommended to patients who are unhappy when divorced from the pleasures and excitements of town life. Also it is somewhat isolated, and serious cases of organic disease should not lightly be sent there. Cases of severe heart disease or with advanced degenerative changes in the arteries may be better suited by a place at lower altitude, and the same applies to emphysema and renal disease, though the rule is by no means invariable. It is almost unnecessary to repeat the warning that acute cases of any kind should not be sent, for this applies to all mineral-water health resorts; spa treatment is for chronic and subacute stages only.

The Government Sanatorium.—This institution is intended primarily for patients of the hospital class, and is in charge of a Resident Medical Officer, to whom application for admission, supported by a medical certificate as to fitness for mineral-water treatment, must be forwarded, and by whom patients are also examined before admission.

WAI-O-TAPU

Wai-o-tapu, 21 miles from Rotorua, on the Taupo road, boasts an enormous number of springs, some of which have an equally enormous outflow. At present the place can hardly be termed a spa at all. It consists of one country

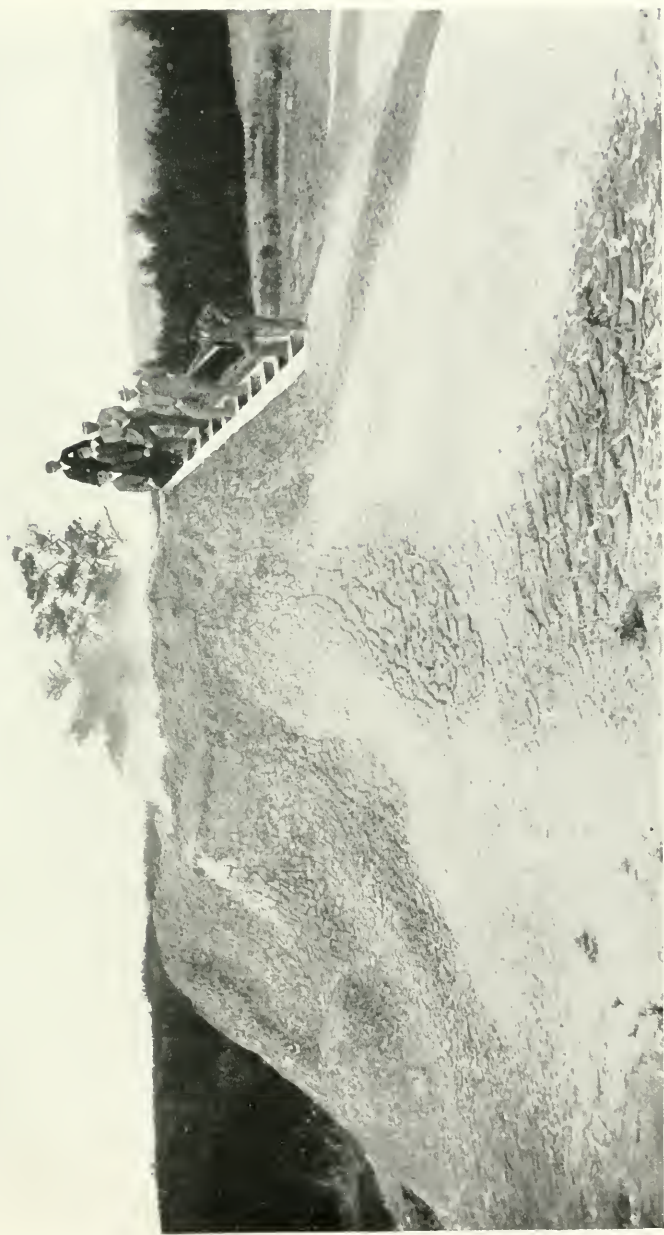


FIG. 60.—MUD VOLCANO, WAI-O-TAPU.

This is by far the largest cone in the district, and has resisted denudation for many years.



FIG. 61.—THE "DEVIL'S BRIDGE," WAI-O-TAPU.
This is a natural arch of silica bridging boiling horrors below.



FIG. 62.—THE "ECHO LAKE," WAI-O-TAPU.

A volcanic lake of cold placid green water encircled by glowing coloured cliffs.



hotel set in the midst of a veritable inferno of steaming sulphurous springs; and on a damp day, when every puff of steam shows up, the traveller may well wonder how it can ever be approached at all. Even beyond its immediate confines there is abundant evidence of fierce thermal activity. One approaches, past Maunga Kakaramaea, or Rainbow Mountain, a volcanic peak of variegated clay, red and yellow, purple and white, with vivid green pools of mineral water at its base; in the tea-tree scrub the steam curls lazily from numerous hidden pools of boiling mud, while in the background, high aloft, puffs of steam issue from the sides of Maunga Onga-Onga, suggesting irresistibly the smoke of well-concealed guns. On the plain beyond, though hidden from sight, runs an actual river of hot water, its course marked by a thin line of vapour.

Access.—By road from Rotorua or Taupo.

Climate.—The climate resembles that of Rotorua, but is more bracing, and distinctly colder in winter.

The Waters.—No waters at present are used for drinking purposes, and indeed, as already explained, Wai-o-tapu is rather a tourist resort than a spa. The springs are not only huge in output, but varied in constitution. Only a small proportion of these has yet been analysed, and already at least four different types have been shown to exist, though all are sulphuretted.

(a) There is a large group characterized by feeble mineralization, and containing a small quantity of sodium chloride, of which the “Roadman’s Bath” may be taken as a type (for analysis see p. 102).

(b) Another subclass, of which the Champagne Pool is the principal example, is richer in salts, and, in addition, contains large amounts of free carbonic acid gas (analysis, p. 102).

(c) A third subclass exhibits free sulphuric acid, and is especially noteworthy as being one of the few exceptions to the rule that the boiling springs are always alkaline. The Sulphur Terrace Spring is a typical example (for analysis see p. 102). The boiling water as it runs down rocky

ledges has formed beautiful little terraces of pure sulphur. The spring evidently represents the condensation of a fumarole laden with sulphurous acid, a solfatara. The sulphurous acid on exposure is oxidized to sulphuric acid, and sulphur is deposited.

(d) A fourth subclass is highly aluminous.

Other waters offer striking physical contrasts of colour and texture, due in some cases to precipitation of sulphur, in others to the presence of iron salts and of various silicates, but in numberless others to causes as yet not accurately determined. Some of the hot springs too, especially some arising in the bed of the creek, contain quite appreciable quantities of petroleum.

In addition to the mineral waters there are hot mud springs and mud volcanoes, including the largest mud cone of the district (vide fig. 60), and numerous fumaroles and solfataras.

Baths.—With all this wealth of material there are only one or two baths of the most primitive description, so that Wai-o-tapu can at present be reckoned as only a potential spa.

WAI-O-TAPU WATERS (1909)

(Results expressed in grains per gallon)

| — | Champagne Pool | Sulphur Terrace. | Roadman's Bath. |
|---------------------------|----------------|------------------|---------------------|
| Potassium chloride . . | 16.8 | 2.2 | 2.6 |
| Sodium chloride . . | 220.4 | 16.1 | 40.9 |
| Sodium sulphate . . | — | 2.6 | 7.1 |
| Calcium sulphate . . | 6.6 | 1.7 | 1.8 |
| Magnesium sulphate . . | — | 0.4 | — |
| Ferrous sulphate . . | — | 0.5 | — |
| Calcium bicarbonate . . | 3.5 | — | — |
| Sodium silicate . . | 41.0 | — | 17.3 |
| Silica . . | — | 17.6 | — |
| Total solids . . | 288.2 | 41.1 | 69.7 |
| Carbonic acid (free) . . | 13.2 | 2.1 | — |
| Sulphuric acid (free) . . | — | 2.5 | — |
| Sulphuretted hydrogen . . | 1.8 | trace | trace |
| Temperature . . | 212° F. | 212° F. | 212° F. (at source) |



FIG. 63. NATURAL WARM SWIMMING-BATH, WAIRAKEI

The stream of hot mineral water is formed by the overflow of numerous springs.

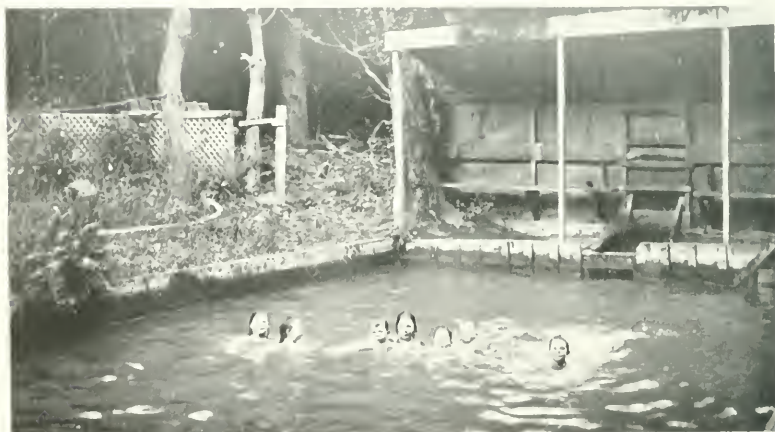


FIG. 64.—THE WARM SWIMMING-BATH, WAIRAKEI.



FIG. 65.—THE "GREAT GEYSER," WAIRAKEI.



FIG. 66.—THE "DRAGON'S MOUTH" GEYSER, WAIRAKEI.



FIG. 67.—THE OUTFLOW OF BOILING WATER FROM THE GREAT GEYSER, WAIRAKEI.

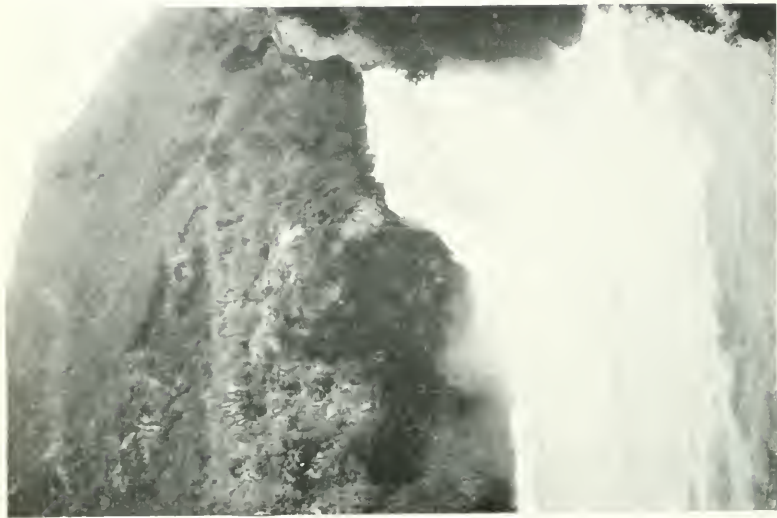


FIG. 69.—THE HUKA FALLS, WAIRAKEI.

Here the Waikato River, after passing over a series of rapids, is narrowed between perpendicular walls, straight channelled as though by art, and falls in one grand sweep of clear green foaming water into a broad whirlpool.



FIG. 68.—KERAPITI BLOW-HOLE, WAIRAKEI: ONE OF THE "SAFETY-VALVES" OF THE DISTRICT.



FIG. 70.—THE ARATIATIA RAPIDS, WAIKATO RIVER, WAIRAKEL.

These three waters together with an aluminous water represent the main types existent at Wai-o-tapu. The Champagne Pool is a saline water with abundant carbonic acid and a moderate amount of sulphuretted hydrogen ; it is the largest spring of its class in this district.

The Sulphur Terrace Spring is particularly interesting in that it represents one of the rare exceptions to the rule that the sulphuric acid waters are always found much below the boiling-point. The water flows out over a series of beautiful bright-yellow terraces gleaming with sulphur crystals formed by the deposition of sulphur in the process of the oxidation of sulphurous to sulphuric acid.

The Roadman's Bath Spring is an example of the numerous " simple thermal " springs common throughout the thermal district. Such waters, neutral or alkaline in reaction, are of the variety classed as " deep " waters in the chapter dealing with the genesis of the waters (vide p. 24) and are found in the geysers.

WAIRAKEI

Wairakei, 30 miles beyond Wai-o-tapu on the road to Taupo, is again a tourist centre rather than a spa, and is famed more for its beautiful and fantastic geysers than for the therapeutic virtue of its springs. This is not because of any lack of medicinal value in the waters, but simply because, from want of development, the waters are, so to speak, lying fallow.

Access.—By road from Rotorua or Taupo.

Climate.—Bracing upland inland atmosphere. There is abundant sunshine, but at times cold winds blow off the snow mountains to the south.

The Waters.—The springs are all extremely hot siliceous sulphur waters. These waters, though varying very greatly amongst themselves in regard to minor details of analysis, would appear to be divisible roughly into two main groups.

Thus all the waters, or at any rate all those that have so far been examined, of the Geyser Valley are muriated (cf. analysis of Champagne Pool, p. 109), while those of the Kiriolinekei Valley contain sulphuric acid (cf. analysis of " The Boilers," p. 109). Though the waters are drunk by a few invalids, it has been hitherto on no defined plan, and there is practically no record of the therapeutic effects,

Of course the waters of the Kiriohinekei Valley are not potable.

The Baths.—The baths are primitive but exceedingly delightful ; indeed, I do not know any bath that for sheer



FIG. 71.—THE "TWINS" GEYSER, WAIRAKEI, IN ACTIVITY.

luxury of surroundings quite equals the hot swimming-bath under the trees in the gardens of Wairakei. But little attempt has been made to cater for invalids, Wairakei being pre-eminently a tourist centre.

Perhaps this is not to be wondered at when one considers its attractions. The Geyser Valley is the very quintessence

of the thermal sights of New Zealand. Elsewhere there may be finer geysers, but here they are more beautiful, and they are active at such frequent intervals that one may always be sure of seeing at least two or three "playing." The silica formation, too, is peculiarly and fantastically beautiful (cf. fig. 66), and there is also the largest and most famous fumarole of New Zealand, the Kerapiti blow-hole (fig. 68).

In addition to thermal sights, there is the great Waikato



FIG. 72.—MOUTH OF THE "TWINS" GEYSER.

River in its most picturesque mood, now thundering over the superb Huka Falls, now roaring down the Aratiatia Rapids, and, in its quieter reaches, a peculiarly happy hunting-ground for the trout-fisher. (For table of analysis of mineral waters see p. 109.)

TAUPO

Taupo is the most inland and the most elevated of the mineral-water health resorts of the North Island. It is situated on the northern shore of the lake—Taupo Moana—

at the point of emergence of the Waikato River. Across the lake is an impressive panorama of snow-topped volcanoes, Rnapehu, Tongariro, Te Mari, and Ngauruhoe, the two last-named still active, while behind it to the north frowns the extinct cone of Tau Hara. Round the base of this mountain rise numerous hot springs and geysers of the type with which we are already familiar.

Access.—By road from Napier or Rotorua, or across the



FIG. 73.—THE "EAGLE'S NEST" GEYSER, WAIRAKEI.

The geyser arising in Manuka scrub, the ground strewn with abundant dead branches; some of these latter have become silicified and cemented together round the mouth of the geyser. It is probable, however, that nature has been assisted by art.

lake from Tokaanu, and thence by road from the Main Trunk Railway.

Climate.—Practically in the centre of the island, the modifying effects of a sea climate are minimized as far as is possible in so narrow a country as New Zealand. The altitude is from 1,200 to 1,400 feet, and the air from the snow mountains is keen and bracing; at the same time there is a large amount of sunshine, and the direct rays of the sun are hotter than in the lowlands, while the shade temperature



FIG. 74.—THE "CROW'S NEST" GEYSER, TAUPŌ.
Compare the cone of this geyser with the "Brain-pot" (Fig. 16).



FIG. 75.—A BOILING SPRING, TAUPO.

is lower, and the nights are cool even in summer. As a result the climate is tonic and bracing.

Like Wairakei, Taupo is the resort rather of the tourist than the invalid, still it has certainly more claims to the title of "spa" than any other place in the Thermal District except Rotorua.



FIG. 76.—THE DINING-HALL, THE SPA, TAUPŌ: A MAORI CARVED HOUSE CONVERTED TO ITS PRESENT USE.

The Springs.—There are geysers and hot springs alongside the Waikato, and others at the mountain foot, but the springs in actual use are in two valleys, at the "Spa" and at the "Terraces." The former lies in a sheltered valley, a garden hidden in a steep-walled hollow below the surface of the surrounding plain. In consequence of its sheltered position, and the number of hot springs, the climate of this little

valley is very much milder than that of Taupo generally. There is an accommodation house of bungalow fashion, while simple immersion baths have been erected in the grounds, and streams of hot mineral water meander through the gardens and under the rose arbours.

The Terraces Hotel, on the other hand, stands a couple of hundred feet higher, and enjoys a dry, bracing climate, while immediately alongside lie the springs and baths in a garden at the bottom of a deep ravine whose climate resembles that of the Spa. These contrasting climates should be borne in mind when ordering patients to Taupo, as a tonic or sedative climate can be selected at will.

The Baths.—At the Spa the baths are of the simple immersion type, large wooden piscinæ; at the Terraces there are similar baths, but there is also a choice of a “spout bath,” a hot waterfall which acts as a simple but effective douche, and of a large open-air hot swimming-bath. It is a curious feature that fish live and thrive in the hot stream that escapes from this bath.

The Waters.—The visitor must not be misled by the local titles of the springs, for some of the names have been originally given on sheer conjecture, and have stuck. Thus at the Spa the “Arsenic Spring” contains no arsenic, but is a chalybeate, and the “Iodine Spring” contains no iodine.

At the Spa the principal waters, then, are a mild chalybeate containing 0.56 grain per gallon of ferrous bicarbonate, several sulphuretted saline waters, and others containing alum.

At the Terraces there is a mild, hot chalybeate water, and another cold but containing more ferrous bicarbonate (0.84 grain), and bubbling with carbonic acid. There are also numerous hot sulphuretted saline waters, and one hot borated water, while several of the Taupo waters contain small quantities of sodium iodide. (For further analyses see p. 109.)

Indications.—Taupo is an excellent spot for *recuperation in convalescence* from acute disease, but patients of this class

THE TAUPO AND WAIRAKEI WATERS

| | Magnesia T.T. | Magnesia T.T. | Top Spring T.T. | Soda Water T.T. | South Bay T.T. | Iron Bath T.T. | Cold Soda T.T. | Arsenic S.T. ¹ | Iodine S.T. ² | A.C. Bath T. | Soda Water S.T. | Old Sul- phur S.T. | Iron S.T. | Cham- pagne W. | Devil's Eyeglass W. | Boilers W. | Red Coral W. |
|-----------------------------|------------------|------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|------------------------------|-----------------------------|--------------------|-----------------------|-----------------------------|--------------|----------------------|---------------------------|---------------|--------------------|
| Potassium chloride . . . | 4.55 | 2.80 | 3.64 | 0.42 | 3.8 | 1.4 | 0.50 | 1.1 | 0.60 | 0.34 | 0.95 | 1.05 | 1.26 | 7.56 | 2.80 | 2.70 | 5.90 |
| Sodium chloride . . . | 45.45 | 43.66 | 50.32 | 0.82 | 56.10 | 14.65 | 0.34 | 0.81 | 1.25 | 1.45 | 1.09 | — | 13.32 | 195.20 | 63.85 | 39.35 | 152.48 |
| Sodium sulphate . . . | 7.31 | 7.87 | 9.18 | 5.54 | 8.56 | 2.57 | 3.18 | 10.58 | 6.55 | 1.70 | 4.67 | 7.32 | 7.52 | — | 7.35 | 14.50 | — |
| Sodium bicarbonate . . . | 2.00 | 9.46 | 9.73 | 1.12 | 3.65 | 7.32 | — | 3.60 | — | 3.50 | 1.50 | 2.52 | — | 1.20 | — | — | 1.30 |
| Sodium silicate . . . | 24.55 | 23.20 | 25.00 | 5.95 | 26.90 | 15.75 | — | 31.12 | 22.50 | 13.10 | 17.32 | 19.20 | — | 27.95 | — | — | 23.10 |
| Ferrous bicarbonate . . . | — | 0.16 | 0.28 | 0.84 | 0.12 | 0.28 | — | 0.56 | 0.28 | 0.12 | 0.12 | 0.06 | 0.04 | 0.06 | 1.20 | 1.12 | 0.16 |
| Calcium bicarbonate . . . | 2.78 | 1.26 | 1.86 | 1.68 | 3.69 | 3.87 | — | 3.60 | 2.70 | — | — | — | — | 5.40 | — | — | 0.72 |
| Calcium sulphate . . . | — | — | — | — | — | — | 2.16 | — | — | 2.95 | 3.20 | 4.17 | 2.68 | 3.06 | 6.68 | 5.71 | 2.04 |
| Magnesium sulphate . . . | 0.63 | 0.27 | 0.27 | 0.12 | — | 0.30 | 0.33 | — | 0.15 | 0.27 | 0.54 | 0.27 | 0.27 | 0.75 | 0.75 | 0.69 | 0.78 |
| Magnesium bicarbonate . . . | — | — | — | — | — | — | — | 0.25 | — | — | — | — | — | — | 24.72 | — | — |
| Silica . . . | — | — | — | — | — | — | 6.02 | — | — | — | — | — | 11.84 | — | — | — | — |
| Sodium borate . . . | 3.69 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Sulphuric acid (free) . . . | — | — | — | — | — | — | 0.49 | — | — | — | — | — | — | — | — | 4.50 | — |
| Carbonic acid (free) . . . | 17.75 | 1.91 | 4.62 | 47.70 | 4.60 | 16.90 | 15.40 | 0.90 | 11.5 | 22.80 | 2.46 | 28.60 | 2.20 | 1.40 | 7.10 | 7.50 | 0.80 |
| Hydrogen sulphide . . . | — | — | — | — | — | — | — | — | — | 0.20 | — | 0.60 | — | 0.10 | — | — | — |
| Ferrous sulphate . . . | — | — | — | — | — | — | 0.12 | — | — | — | — | — | — | — | — | — | — |
| Aluminium sulphate . . . | — | — | — | — | — | — | 0.27 | — | — | — | — | — | — | — | — | — | — |
| Total . . . | 108.78 | 90.59 | 105.8 | 64.19 | 107.72 | 63.04 | 28.81 | 52.52 | 45.53 | 46.43 | 31.85 | 63.79 | 40.63 | 242.68 | 117.25 | 100.77 | 193.28 |

T. = Taupo.

T.T. = "Terraces," Taupo.

S.T. = "Spa," Taupo.

W. = Wairakei.

¹ Contains no arsenic.

² Contains no iodine.

should be warned to be very sparing in the use of the tempting hot baths. The cold chalybeate water at the Terraces would, however, be beneficial in patients who are still anæmic.

Chronic arthritics do well taking the open-air and semi-open-air baths, combined with the bracing air and abundant sunshine they are likely to obtain. If sulphur waters are drunk they should be the saline waters rather than the borated so-called magnesia spring.

TOKAANU

Tokaanu, on the south side of Lake Taupo, contains numerous hot springs closely resembling those of Taupo and Wairakei. There is a concrete public immersion bath available, but no balneological appliances or resident doctor, and the place is a tourist rather than an invalid resort.

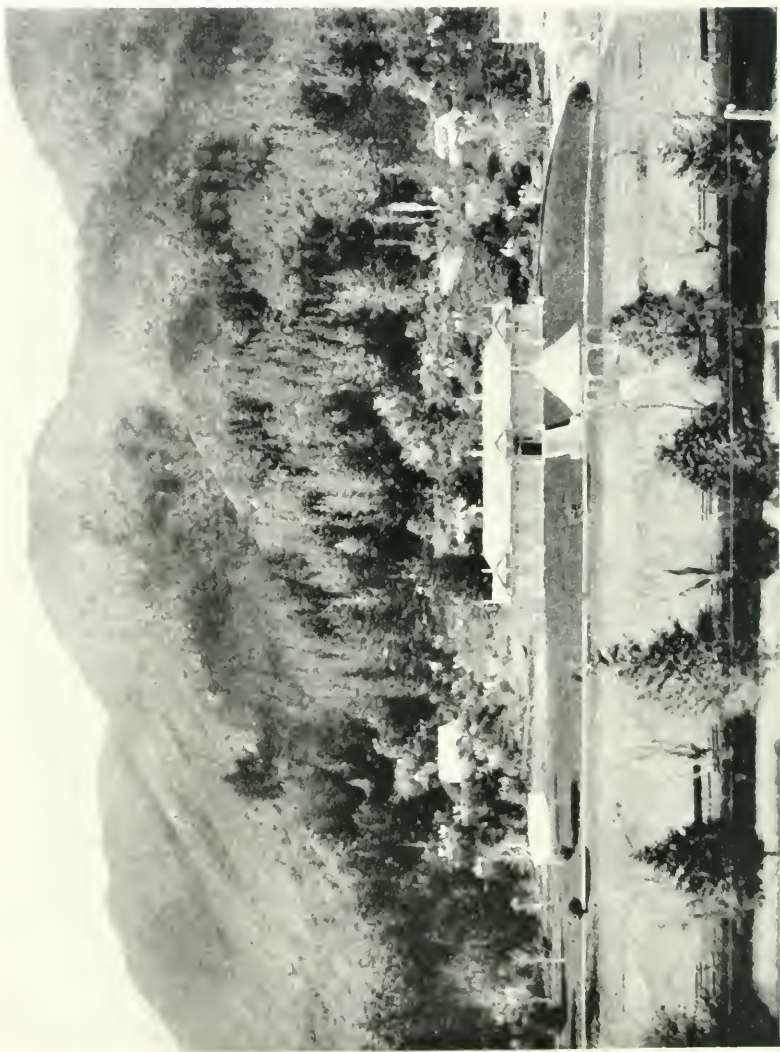


FIG. 77.—THE BATHS, TE AROHA.

CHAPTER VII

THE ALKALINE SPAS

TE AROHA

THIS is a pretty little watering-place nestling at the foot of Te Aroha¹ Mountain, a picturesque and forest-clad peak standing out boldly at an angle of the Paeroa Range. In front, over the winding Waihou River, it overlooks the broad valleys of the Thames and Waikato. Formerly a gold-mining township, it is now the centre of a rich pastoral district which brings it an even greater and certainly more permanent prosperity.

The springs, over twenty in number, but, according to the lavish New Zealand standard, somewhat limited in outflow, are scattered over an extensive public garden on the lowermost slopes of the mountain, and a number of bath-houses are dotted about the grounds, their situation generally determined by the outcrop of the principal springs.

Most of the springs are hot, and the baths, while not imposing, are comfortable. While at Rotorua the life of the place centres round the baths, at Te Aroha it is round the springs; the former is essentially a *bathing* resort, the latter more especially a place for *drinking* the waters.

Access.—By train via the Rotorua line, or for Auckland visitors, there is an alternative route by boat to the Thames, and thence by train.

Climate.—The climate is mild and sedative, an observation emphasized by the fact that Te Aroha marks the southern

¹ "Aroha"—"love" in Maori.

limit of the kauri belt.¹ In elevation it is for the most part very near the sea-level, though sufficiently raised by the extreme mountain-foot to be above the damp of the valley. The close proximity of the mountain, while sheltering the town from the north-east winds, has the disadvantage of cutting off some of the early morning sun, especially in winter, and of causing an eddy at times of gusty westerly winds. On the whole, however, the climate is essentially suited for invalids requiring a mild, warm, and sedative climate.

The Season.—The baths are open all the year round, but the season is from November to April.

Accommodation.—There are several hotels and boarding-houses abutting right on to the public gardens.

Amusements.—The public gardens are laid out for tennis, bowls, and croquet, and there are some inviting clambers on the mountain-side for those whose physical infirmities do not preclude exertion; but the gaieties of some of the European Continental spas are conspicuous by their absence. Te Aroha is rather a quiet, restful resort set amongst charming natural surroundings.

The Mineral Waters.—There are three types of waters, the *thermal alkaline*, the *cold chalybeate*, and the *magnesia*. Of these, the first waters are much the most important, and are what are always meant when Te Aroha waters are spoken of, while the two latter are really variants of one type.

GROUP I. THE ALKALINE WATERS

The Alkaline Waters.—The majority of the springs conform to this type, resembling the waters of Vichy (France), but containing a very much larger percentage of sodium bicarbonate, and ranking as one of the strongest and, with the exception of certain American waters, probably the

¹ The magnificent kauri forests, now, alas! fast disappearing, flourished in New Zealand only in the northern extremity of the North Island. They appear to require an almost sub-tropical climate.



FIG. 78.—THE BOWLING GREEN, TE AROHA.

114 THE HOT SPRINGS OF NEW ZEALAND

| RADIO-ACTIVITY OF WATERS ¹ | | | RADIUM CONTENTS OF WATERS ¹ | | |
|---------------------------------------|--------|---|--|--------|---|
| No. | Spring | Activity, Radium grammes $\times 10^{-12}$ per c.c. | No. | Spring | Activity, Radium grammes $\times 10^{-12}$ per c.c. |
| No. 2 | Spring | 0.026 | No. 2 | Spring | 0.0009 |
| " 6 | " | 0.015 | " 6 | " | 0.0002 |
| " 8 | " | 0.010 | " 8 | " | 0.0010 |
| " 15 | " | 0.031 | " 15 | " | 0.0012 |
| " 20 | " | 0.056 | " 20 | " | 0.0005 |
| " 22 | " | 0.130 | | | |

actual strongest ² alkaline thermal waters in therapeutic use. As in other waters of this type, there is also a certain amount of sodium chloride present; indeed, the amount is almost sufficient to put this water in the class of muriated alkaline waters of the Ems and Royat type, and some of the springs certainly might so be included.

There is also a considerable amount of free carbonic acid gas, again as at Vichy and Ems, the amount varying in different springs.

The amount of calcium bicarbonate is small, too small probably to have any marked pharmacological value, and there is a small amount of magnesium bicarbonate in all the waters, and a varying amount of sodium sulphate.

The temperature of the several springs varies considerably, but the main sources are constant at 135° F.

Pharmacological Action. Sodium Bicarbonate.—Some-what conflicting views have been held as to the action of sodium bicarbonate in the stomach. It was formerly generally held that small doses stimulated and large doses inhibited gastric glandular activity. The experiments of Pawlow and of Bickel would, however, indicate that the alkali, even in small doses, has a depressing rather than a stimulating effect on gastric and pancreatic secretion, and acts beneficially by giving a rest to the glandular apparatus during the period when secretion is not required. Linossier,³

¹ Maclaurin and Wright, *Annual Report, Dominion Lab.*, 1911.

² The Castalian Springs, California, contain 1,724 grains, and the Saratoga Springs, New York, up to 818 grains per U.S. gallon of alkaline carbonates.

³ *Ann. de l'Acad. de Méd.*, Paris, April 14, 1908.

however, in a more recent investigation, reverts to the older opinion, and maintains that sodium bicarbonate stimulates the secretion of hydrochloric acid. He says that the alkali acts in two ways: (1) the immediate chemical action neutralizes free acid; (2) further action stimulates the secretion of hydrochloric acid but not of pepsin, so that the final result is an increase of acid.

To increase gastric acidity the alkali should be given before meals; to neutralize excessive acidity large doses should be given two hours after food, so that the food leaves the stomach before the drug causes a further stimulation of the hydrochloric acid. From this it is obvious that the motor activity of the stomach must largely determine whether the soda acts as an acidifier or as an antacid.

In an earlier paper¹ the same observer advocates, in hypo-acidity, small doses fifteen minutes before a meal, or large doses an hour before. Large doses cause a feeling of satiety, which is gradually followed by increased desire for food, the hydrochloric acid being first neutralized and then a greater flow being stimulated. In hyper-acidity he gives small doses every half-hour during digestion, beginning from the time that the pain comes on and continuing till digestion is finished.

Te Aroha water, however, is by no means a simple alkaline water, and the presence of common salt and of carbonic acid, both of which are stimulants to the gastric mucous membrane, must at any rate diminish any inhibitory power that sodium bicarbonate may possess.

Alkaline waters are diuretic, and increase the solvent power of the urine for uric acid, and their diuretic power is enhanced by the presence of carbonic acid gas. The urine at the same time is rendered neutral or alkaline. They temporarily increase the alkalinity of the blood,² and so increase the consumption of oxygen and the output of carbonic acid, thereby stimulating both nitrogenous and non-

¹ *Journal des Practiciens*, 1895.

² Kisch, *System of Physiologic Therap.* (Cohèn)

nitrogenous metabolism. Mucus is more readily dissolved, alike in the stomach, the bronchi, and in the bladder, and, as a consequence, gastric catarrh may be relieved, expectoration in bronchitis eased, and conglomerate stones held together by mucus may be broken up. As there is also a cholagogue action, the use of these waters in biliary concretion is explained.

Purely alkaline waters are "lowering," and are more suitable for stout, plethoric patients than for the thin and debilitated. Te Aroha water, however, as we have seen, is not a purely alkaline water, but is rather intermediate in type between the alkaline waters of Vichy and the alkaline saline, such as those of Ems.

Sodium Chloride.—The action of this salt is in some directions opposite to that of the bicarbonate, so that in Te Aroha water it acts like the "corrective" in a prescription. It stimulates the mucous membrane of the stomach and intestine, and makes the water less "lowering." At the same time it tends, while increasing peristalsis, to render the contents of the bowel more fluid, and acts both as a laxative and diuretic. As these waters contain fair quantities of sodium sulphate, their action should be somewhat purgative. As a matter of fact, their action in this respect is very small and varies in different individuals.

The ingestion of sodium chloride increases the amount of salt excreted by the kidneys, and this favours both the solubility of uric acid and its elimination.¹ It also promotes the absorption and assimilation of nutritive material, and so promotes nutrition.

Indications.—*Gastric catarrh and hyperacidity, gout in sthenic cases, gouty glycosuria, biliary calculus, uric-acid calculus, and chronic catarrh of the respiratory organs.*

The usual initial dose of the waters is a small glass (6 to 8 ounces) twice daily an hour before or two hours after a meal. This may be increased gradually, in suitable cases, to a large glass (10 ounces) three times a day. In gouty cases

¹ Weber, *Climatotherapy and Balneotherapy*.

more especially it is well to proceed cautiously, or most unpleasant exacerbation of symptoms may ensue. In biliary calculus the case must be carefully watched. We may anticipate, in favourable cases, a mechanical sweeping out of micro-organisms and toxins from the gall bladder, and a disintegration of concretions, but the danger of impaction is always present. *After* operation, however, a course of mineral water is free from objection, and may do great good in many cases.

In renal calculus even more caution is needed. If one can be sure that the stone is pure, or nearly pure, uric acid, there is a reasonable hope that it may be so reduced in size as to pass the ureter, though here again there is obvious danger; but the cases in which such assurance can be held are so rare as to be almost negligible.¹ Should the stone, on the other hand, prove to be composed of calcium oxalate or phosphate, as is much more probable, only harm will come of giving Te Aroha water. Stone in the bladder is more likely to consist of uric acid, and again its character is more easily gauged, so that in bladder cases this water is more useful. I have several times seen uric-acid stones passed during a course of these waters. They have generally been multiple, small, rounded uric-acid masses about $\frac{1}{16}$ inch in diameter, seldom larger, not faceted, and probably formed in the bladder. Larger so-called uric-acid stones, definitely located in the kidney, are generally of mixed

¹ Benjamin Moore ("The Chemical Composition and Mode of Formation of Renal Calculi," *B.M.J.*, April 1, 1911), making a quantitative analysis of 24 stones, found in 21 cases from the kidney and ureter, and one from the prostate, an enormous preponderance of calcium oxalate and phosphate, and a very small percentage of uric acid, and that largely in the form of the insoluble calcium urate. Two stones taken from the bladder consisted of almost pure uric acid. As the solubility of calcium oxalate and calcium phosphate is enormously decreased by increased alkalinity, it is obvious that in 22 cases out of the 24—that is, in all the kidney cases—harm would have been done by giving an alkaline mineral water. Indeed, it would appear probable that it is on their solvent action on bladder-stones, which may consist of almost pure uric acid, that the reputation of alkaline mineral water in urinary cases rests.

constitution, and the solvent action on them of the alkalies is more than doubtful. The use of the waters in diabetes must be guarded by certain well-defined reservations. Young, thin, asthenic subjects, in fact grave cases generally, should not be sent to Te Aroha; while plethoric, middle-aged gouty people—cases of gouty glycosuria—may do very well indeed. It is well to remember, however, that little facility exists for special dieting, and that unless a patient is prepared to take a furnished house he may have almost insuperable difficulties in obtaining a proper dietary.

Contra-indications.—*Gout* in the acute, or threatening the acute stage, *asthenic gastric hypo-acidity*, and the *atonic dyspepsia of anæmia*.

ANALYSIS OF WATERS

(In grains per gallon)

GROUP II. THE COLD MAGNESIUM WATERS

| | Spring No. 20 (1904). | Spring No. 21 (1904). | Spring No. 22 (1903). |
|-----------------------------|--------------------------|--------------------------|--------------------------|
| Sodium chloride . . . | 1.9 | 23.9 | 26.57 |
| Sodium bicarbonate . . . | 3.3 | 258.1 | 179.81 |
| Sodium sulphate . . . | 9.1 | 9.3 | 18.19 |
| Potassium chloride . . . | 1.3 | 4.1 | 1.08 |
| Calcium bicarbonate . . . | 8.9 | 31.5 | 31.82 |
| Magnesium bicarbonate . . . | 11.9 | 13.3 | 11.24 |
| Ferrous bicarbonate . . . | 1.2 | 0.7 | 0.12 |
| Lithium chloride . . . | — | — | traces |
| Silica | 4.5 | 13.5 | 3.92 |
| Total solids | 42.1 | 354.4 | 272.75 |
| Free carbonic acid . . . | 60.4 | 103.4 | 71.0 |
| Temperature (Fahr.) . . . | Cold | Cold | Temid |

GROUP II. THE MAGNESIUM WATERS

All the alkaline thermal springs contain a certain amount of magnesium bicarbonate, but the quantity is so small as to be almost negligible; the cold and subthermal springs,

on the other hand, while more weakly mineralized, contain an appreciable amount of the magnesium salt. They arise principally at the eastern extremity of the gardens, a second group springing from private property a few yards away. They are pleasant to drink, the faintly sweet taste masked by a slight flavour of iron; indeed, spring No. 20 contains almost enough ferrous bicarbonate to be classed among the chalybeates.

In addition to these salts there is calcium bicarbonate to the extent of over 30 grains per gallon, so that the resemblance of these waters to some of the calcareous waters of Europe, especially Wildungen, is very close indeed. Where they differ is in the large amount of sodium bicarbonate, though this is in less quantity than in the thermal alkaline waters. There appears also to be an appreciable but variable amount of *lithium chloride* in these springs. The amount has varied from "a trace" to 1·2 grain per gallon (1913), and may possibly have a specific action in gout, for the effect of even minute doses in the form of dissociated ions may be made greater than that of similar doses of the salt in ordinary form.¹

Pharmacological Action. — In addition to the actions already noted of the sodium chloride and bicarbonate, the calcium salts, by their astringent effect, act beneficially in irritable digestive troubles, and in large doses are diuretic, though it is very doubtful whether they increase the output of uric acid. The magnesium salt is also antacid and sedative, though its action on the bowel is neutralized by the calcium. The possible effect of lithium has already been considered.

Spring No. 20 is a weakly mineralized variant of the other cold springs, but contains 1·2 grain of bicarbonate of iron, and, also like the other springs, a fair amount of carbonic acid. It is thus a mild, pleasant chalybeate, easily borne in cases of anæmia with feeble digestion and irritable stomach.

A few miles away at Paeroa there is a large, warm, effe-

¹ Cf. lithium salts in Hanmer waters, p. 95.

vescing spring of very closely similar nature, but containing 73 grains of magnesium bicarbonate to the gallon. It is a corrective of acid dyspepsia, and a pleasant drink withal, and had in the old days, I am told, a reputation among the gold-miners of the district as a Sunday-morning drink after a "Saturday-night burst."

Indications for Magnesium Water.—*Dyspeptics* and *gouty* cases with irritable stomach, who do not tolerate the thermal alkaline water; cases of *anæmia* with feeble digestion (Spring 20).

GROUP III. THE CHALYBEATE WATERS

In a garden a short distance to the east of the Public Gardens arises a group of cold springs closely resembling Group II, the magnesium springs. One of these, however, is considerably richer in the iron salt and deserves to be more generally known. Their on is in the easily assimilable form of ferrous bicarbonate, and is associated with small quantities of earthy and alkaline carbonates: as the amount of free carbonic acid is considerable, the water is also extremely palatable.

COLD SPRINGS (1913)

(Analysis expressed in grains per gallon)

| — | Spring No. 1. | Spring No. 2. | Spring No. 3. | Spring No. 4. | Spring No. 5. | Spring No. 6. | Spring No. 7. |
|-----------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Sodium chloride . | — | 0.7 | — | — | — | — | — |
| Lithium chloride . | — | — | traces | — | — | traces | 0.14 |
| Sodium bicarbonate . | 2.17 | 0.21 | 3.43 | 4.76 | 4.34 | 6.44 | 5.67 |
| Magnesium chloride . | 1.33 | 1.19 | 1.89 | 2.03 | 1.68 | 1.54 | 1.54 |
| Magnesium sulphate . | 2.31 | 0.42 | 0.42 | — | — | — | — |
| Calcium bicarbonate . | 15.40 | 7.91 | 27.30 | 22.12 | 15.89 | 48.16 | 25.90 |
| Magnesium bicarbonate | 0.49 | — | 12.25 | — | 5.39 | 15.40 | 11.27 |
| Ferrous bicarbonate . | 4.55 | 0.35 | 0.14 | 0.35 | 0.91 | 0.14 | 0.07 |
| Alumina . | 1.89 | 0.21 | 0.21 | 0.84 | 0.35 | 0.98 | 0.56 |
| Sodium silicate . | 5.11 | 5.32 | 5.32 | 3.78 | 5.88 | 6.23 | 5.39 |
| Total solids . | 33.25 | 16.31 | 50.96 | 33.88 | 34.44 | 78.89 | 50.54 |
| Free carbonic acid . | 76.93 | 59.29 | 0.7 | 71.82 | 74.34 | 53.41 | 36.89 |

Indications.—Cases of *anæmia* with delicate digestion and most cases of *chlorosis*. As the amount of associated magnesium salts is small, it may be advisable to administer simultaneous doses of purgatives.

Dosage.—One small glass (6 ounces), increased later to a large glass (10 ounces), three times a day.

It will be noted that of these springs only No. 1 can be reckoned as a true chalybeate. The remaining waters, while weakly mineralized and lacking the sodium bicarbonate, closely resemble the “magnesia water” found in the Government Gardens. They are calcic-magnesian waters, diuretic and feebly antacid. For geographical reasons, however, and to prevent confusion of identity, these springs are grouped separately here.

The Springs.—The principal sources for drinking the alkaline water are the Octagon Spring (No. 8) and the Pump Spring (No. 15).

These two springs are practically identical in chemical composition, though No. 15 is considerably the hotter, and popular opinion attributes to them different therapeutic properties. They are both alkaline waters of the type predominating at Te Aroha, and these are the springs referred to when the term “Te Aroha water” is used. The “Magnesia Spring” is No. 21, though No. 22 is sometimes used, and the “Iron Spring” is No. 20.

The Baths.—These are supplied by the alkaline thermal waters only, and, as at Rotorua, they are of two main types: the newer or Cadman Baths, in which the water is led in pipes to the establishment, and the older baths, built over the actual springs. The remarks already made in regard to the Rotorua baths (see p. 83) apply here with equal force, and there are certain advantages and disadvantages inseparable from either plan. There has always been a preference among invalids for the public immersion baths in the actual springs where the water and carbonic acid gas bubble up through the floor; and in view of what we have already noted about the quality of “freshness” in

mineral water, and also of the effect on the skin of carbonic acid gas, it would seem that this preference is justified.

No. 2 Bath, which is generally kept at a temperature of from 102° F. to 104° F., is the favourite, though there is a large subthermal bath on similar lines which is more suitable in hot weather for cases in which more tonic treatment is indicated.

The so-called "skin disease bath" is a small private bath supplied from No. 16 Spring, a tepid to cool alkaline water containing a certain amount of sulphuretted hydrogen. It has probably gained its reputation from the deeply rooted popular belief in sulphur as a skin medicament.

The Cadman Baths consist of suites of private immersion baths comfortably housed in a not unpicturesque pavilion. They have the advantage of hotter water and of privacy and cleanliness, but the gas in the water is lost. They are supplied by Springs Nos. 13, 14, and 15.

Indications.—The baths may be used with advantage in conjunction with drinking the waters in nearly all *arthritic cases*. As appliances are of the simplest, immersion baths are the only ones practically available, and for an account of the physiological action of such baths the reader is referred to Chapter XVI.

Apart from this general action, however, the thermal waters, owing to their soft nature and the solvent action of the alkali on sebaceous secretions, are useful as baths in certain skin diseases, especially those of a *seborrhæic* nature. Thus, in cases of seborrhœa of the scalp, and in those very frequent cases in which psoriasis on the body merges imperceptibly into seborrhœa, the alkali forms almost a soap with the sebaceous material, and is of material assistance in removing crusts and scales.

CHAPTER VIII

THE SALINE SPAS

SALINE WATERS

WAIWERA

THIS is a quiet and very charming little spa, hemmed in between high forest-clad hills behind and the blue waters of the Pacific in front. The baths are built on the sandy beach at one end of the bay, at the other a trout stream opens out into the sea; between are one large hotel, a few cottages, and the pier.

Access.—By steamboat or road from Auckland, some thirty miles distant to the south.

Climate.—The climate is mild and equable, and frosts are rare and never severe, so that as a winter resort for those requiring a mild, sedative climate the place has great possibilities. The chief drawbacks in winter are the fairly heavy rainfall and the execrable state of the winter road to Auckland. To counterbalance the rainfall, however, there is at all times of the year a very large amount of sunshine. On the whole, perhaps, the autumn is the most suitable time for invalids, from March almost till July, for the short winter is late in setting in.

The Springs.—These arise on the actual shore, about high-water mark, and some of them below that level.

The Baths.—Simple but comfortable immersion baths have been built over the springs, so that the walls of the building are washed by the sea, but there are none of the accessories that are generally associated with spa treatment.

The Waters.—These are alkaline saline and slightly

chalybeate. Their action is first to neutralize acidity, e.g. in fermentative dyspepsia, and then to stimulate gastric secretion. They tend to liquefy mucus, whether in the alimentary or the bronchial passages, and by liquefying bronchial secretion they facilitate expectoration.

The dose is 10 ounces fresh and hot from the spring, taken two or three times a day on an empty stomach.

ANALYSIS

| | Grains per gallon. |
|-----------------------------|--------------------|
| Sodium chloride | 116.7 |
| Sodium bicarbonate | 87.5 |
| Ferrous bicarbonate | 0.6 |
| Total solids | 219.5 |
| Temperature | 105° F. |

Indications.—Patients seriously ill should not be sent to Waiwera, as there is no resident doctor, but many forms of *dyspepsia*, especially if associated with hypo-acidity, should do well. *Convalescents* and cases of *chlorosis* should take the waters, combined, during most of the year, with sea-bathing. The combination of a mild climate and alkaline saline waters is especially suitable for *chronic bronchitis*.

HELENSVILLE

This place, also north of Auckland, but on the west coast, has recently attracted a good deal of notice, largely by reason of the energy and determination of its management. When first I knew it, one small hand-pump, which the bather worked himself, drew the water from the hot saline spring rising in a boggy field surrounded by the mud flats of an estuary. The field has been drained and replaced by a garden, bores have been sunk for abundant additional mineral water, excellent baths have been built, and boarding-houses and private hotels have sprung up. The original town is situated a mile or so away on the other side of the river.

Access.—By train from Auckland, short in point of distance, but unhappily not so in point of time.

Climate.—The climate is mild and sedative, perhaps somewhat enervating in the summer, and for Auckland people, who naturally constitute the chief visitors, hardly affords sufficient change. There are very many patients, however, for whom such a climate is beneficial and even essential.

The Baths.—There are several immersion baths of the usual type, and a large hot swimming-bath.

The Waters.—These are of the purely saline type, but contain a small quantity of iodide. Their action is diuretic, and they also stimulate the gastric mucous membrane and increase the secretion of hydrochloric acid. Uric-acid excretion is favoured, and general nutrition promoted.

ANALYSIS

| | Grains per gallon. |
|---|--------------------|
| Sodium chloride | 114.46 |
| Sodium iodide | 0.03 |
| Total solids | 134.68 |
| Gases, H ₂ S and CH ₄ | |
| Temperature | 115° to 146° F. |

Indications.—The waters are indicated in *chronic dyspepsia* with hypo-acidity, especially if associated with hepatic engorgement and piles. Similar waters in Europe, containing small quantities of iodide, are given in cachectic and syphilitic conditions. Though the amount of iodide is extremely small, it is not impossible, in view of what we have already discussed in relation to ionized waters, that it may have some therapeutic action. A combination of bathing and drinking the waters is also indicated in chronic *gouty* and “*rheumatic*” conditions, and in some *bronchial* cases.

TARAWERA

Tarawera, on the Taupo-Napier road, has hot springs of no great magnitude, simple immersion baths, and hotel accommodation. The waters are of the muriated type, and contain 0.25 grain of sodium iodide to the gallon. Their action would be practically identical with those of Helens-

ville, but at present they are comparatively little used, and no balneological appliances or medical supervision are available.

ANALYSIS

| | | | | Grains per gallon. |
|-----------------|---|---|---|--------------------|
| Sodium chloride | . | . | . | 80.00 |
| Sodium iodide | . | . | . | 0.25 |
| Total solids | . | . | . | 100.00 |

IODINE WATERS

A class of thermal waters characterized by high mineralization with calcium and sodium chlorides, and very appreciable quantities of sodium iodide and free iodine, is found on the east coast of the North Island. The most important of these springs arise at Morere and Te Puia, and at both of these spots baths and accommodation houses have been erected.

MORERE

Access.—Morere is reached most easily by road from Gisborne, or from Napier via Wairoa.

In the summer this journey is easy enough, in winter the place is practically isolated by the atrocious condition of the clay roads.

Climate.—This is at all times mild and sedative, with heavy rains in the winter.

Accommodation.—Hotel and boarding-house.

The Springs.—Several fairly copious hot springs arise in the bed and sides of a small torrential creek, a circumstance which renders the collection and use of the waters at times somewhat difficult. At the actual source free iodine would appear to be almost, if not quite absent; but a short distance away, especially when the water has been allowed to fall in douche form into the baths, some decomposition of the iodide appears to take place, and free iodine makes its presence known in sufficient quantities to be appreciated



FIG. 79.—A GROVE OF NIKAU PALM AT MORERE.

by its pungent smell and to colour the water pale brown. The average temperature of the springs is 120° F.

The Waters.—In addition to iodine, the waters contain large quantities of calcium and sodium chloride, and are by no means palatable. Hitherto, on account of the somewhat remote position of the springs, they have not been so much used as might be anticipated, and no exact records



FIG. 80.—THE BATH-HOUSE, MORERE, IN A PICTURESQUE SETTING OF NATIVE BUSH.

exist of their therapeutic efficacy, but Kreuznach, which has somewhat similar calcic-sodic-muriated waters, has a great reputation.

At that spa, in addition to bathing, the patients drink two or three glasses of the water on an empty stomach. There too they inhale the spray obtained by letting the water drip from high fences of twigs, and this is believed to be an essential part of "the cure." The cases treated at Kreuznach are those of scrofula and rickets and of catarrh

of the respiratory passages, and also cases of chronic skin diseases and of syphilis.

At Morere the waters are very much stronger, and much smaller doses would be indicated, perhaps three or four ounces, repeated. Here too the iodine, being practically nascent, should have most active therapeutic properties, and I am convinced that at some future date, when the springs become more accessible and better known, they will become famous.

ANALYSIS

| | Grains per gallon. |
|--|--------------------|
| Calcium chloride | 594.78 |
| Sodium chloride | 1,249.67 |
| Sodium iodide | 2.70 |
| (Also sufficient free iodine to tinge the water light brown) | |
| Total solids | 1,899.60 |
| Temperature | 120° F. |

The Baths.—Simple immersion baths have been constructed, but no special hydro-therapeutic apparatus is provided, and there is no resident doctor.

TE PUIA

Tc Puia, north of Gisborne, on the same coast-road as Morere, has springs of a closely similar nature, but weaker, both in total salts and in iodide. For drinking purposes this is not altogether a disadvantage, as they are thereby rendered somewhat more digestible and somewhat less unpalatable. Their action is the same as that of the Morere waters, and they are indicated in the same class of cases.

ANALYSIS

| | Grains per gallon. |
|--------------------------|--------------------|
| Calcium chloride | 153.40 |
| Sodium chloride | 807.75 |
| Sodium iodide | 1.41 |
| Total solids | 978.69 |
| Gas, CH ₄ | |
| Temperature | 150° F. |

The Springs.—These are numerous and have a considerable output. They arise on broken country high above the shore on a picturesque site with a broad outlook over the Pacific.

In addition to the springs, Te Puia is noteworthy for the large amount of free carburetted hydrogen evolved, not only from the springs, but from clefts in the surrounding rocks. In view of the utility of this gas for domestic purposes, it will aid materially in the future development of the spa.

The Baths.—The baths are still exceedingly primitive, and at present are but little used except by the population of the district. There is, however, a well-built hospital close to the springs, and, as the whole district is developing, there can be little doubt that before very long these valuable waters will, as in the case of Morere, attract considerable attention.

Accommodation.—There is an accommodation-house for visitors.

CHAPTER IX

THE CALCIUM SPAS

CALCIC CARBONATED WATERS

KAMO

KAMO is in the centre of an extensive and interesting limestone district, and its waters, as is usual in districts of this geological formation, are calcareous, chalybeate, and abounding in carbonic acid gas. As a spa it is at present suffering from a wholly undeserved obscurity, and there can be no doubt whatever that, when its merits become better known, it will some day become famous.

At present it consists simply of an hotel, with springs and baths in its own grounds, and were it not for its bottled waters, would be a name unknown outside its own little district. It has, however, great therapeutic possibilities, and even in its present state of development is a place to which very many cases might be sent with benefit.

Access.—There is a regular steamboat service from Auckland to Whangarei, a short and easy passage of a few hours, and largely in sheltered waters. The entrance at Whangarei Heads, under the towering limestone cliffs, is exceedingly picturesque, as is the fine harbour itself. From Whangarei is only a short ride through orange groves and orchards, by bus or train, to Kamo.

Climate.—Being so far north, near the sea, and sheltered by hills, the climate is exceedingly mild, as indeed is evidenced by the abundant crops of oranges, lemons, grapes, and other fruits to be seen on either hand. The summer is hot and somewhat relaxing, and the winter, though very mild,



FIG. 81.—LIMESTONE ROCKS, KAMO.
Many of the rocks are weathered to most fantastic shape.

inclined to be wet. On the whole the autumn, March to June, is perhaps the best time for patients to stay.

The Springs.—Two main springs are used—one for bottling the waters and for drinking, and the other for baths—and both foam vigorously with gas, more especially the bathing spring. In addition there is quite a number of smaller springs of the same nature in the neighbourhood, and one or two isolated ones may be found much farther north in the direction of the Bay of Islands.

The Waters.—As already indicated, these are of the alkaline-carbonated-calcareous-chalybeate type, resembling in many respects the famous waters of Contrexéville, but warmer and much more gaseous, and there is an abundant flow.

ANALYSIS

| | Grains per gallon. |
|---------------------------|--------------------|
| Calcium bicarbonate . . . | 57·68 |
| Sodium bicarbonate . . . | 38·64 |
| Sodium chloride . . . | 38·01 |
| Ferrous bicarbonate . . . | 0·28 |
| Total solids . . . | 164·36 |
| Temperature . . . | 78° F. |

The Baths.—As at most New Zealand spas, the baths are of two types, the natural and the artificial. In the former the patient bathes in the actual spring at its natural temperature, in the latter the water is led to the baths and heated.

The natural bath, foaming furiously with carbonic acid, certainly secures the maximum therapeutic effects; at the same time, unless used with much greater caution than hitherto, it is very dangerous. The amount of carbonic acid given off by the spring varies from day to day, so that while sometimes it may form a layer only one or two inches deep over the water, at other times it may be almost as many feet, and the incautious and unattended bather may meet with disaster. Safety could be ensured, though at the cost of a little efficiency, by leading off the waters two or three feet into baths alongside, also by a previous test

of the depth of the gas layer with a lighted match before the bather steps in, and by never leaving him for a moment unattended.

On entering the bath the water, being subthermal, feels chilly, but within a minute or two, as a layer of gas bubbles collects on the skin, this is replaced by a feeling of warmth.¹

There is a very pronounced stimulation of the unstriped muscles of the skin, as evidenced first by "goose-flesh," and later, in male bathers, by a contraction of the dartos which may be so vigorous as to be actually painful.

At the same time the circulation is powerfully affected. The pulse is slowed and strengthened, the skin flushed pink and hyperæmic, and the nervous system is stimulated. In fact, there are all the results, but exaggerated, of the reactive phase (p. 248) of a cold bath. The bath, in fine, is a powerful tonic.

In the hot baths the water is heated before admittance to the baths. As a result, the carbonic acid is driven off and the ferrous bicarbonate decomposed and deposited as oxide, and the quality of "freshness" is lost. As a consequence these baths act as hot mild saline baths, and no more. Were the water heated in the actual bath, as at Nauheim, a good deal of the carbonic acid might be utilized.

Pharmacological Action.—The waters are diuretic and mildly antacid. At the same time the carbonic acid and sodium chloride act as gentle gastric stimulants. The iron, though in small amount, is present in an easily assimilated form, and its absorption is promoted by the presence of carbonic acid.

Indications.—The waters are indicated in many forms of *indigestion*, especially those associated with diarrhœa and irritability of the mucous membrane, or again, with deficient muscular activity of the stomach.

¹ See page 248, on the comparison of the "indifferent temperature" of water and gas.

Cases of *chlorosis* and *anæmia* following loss of blood or delayed convalescence do well. The waters are also indicated in cases of *atonic gout* with anæmia and impaired digestion. When the baths have been arranged on a safer basis they should be invaluable in the treatment of many heart conditions with feeble musculature and failing compensation, and will, I believe, even surpass their celebrated prototype at Nauheim. In the meantime, if taken with due precautions, they are splendid tonics in cases of ordinary *debility*.

CHAPTER X

THE SIMPLE THERMAL SPAS

SIMPLE THERMAL WATERS

SIMPLE thermal springs are common in the lower Waikato Valley, as are hot sulphur springs in the upper course of the river. There are springs of other types, such as a cold chalybeate water at Morrinsville, but the simple thermal type predominates. The best-known springs of this district are at Okoroire, but there are others fully as abundant at Whangape, Matamata, and Waingaro. At the two latter places baths of a very simple type exist.

OKOROIRE

Access.—By train from Auckland or Rotorua.

Climate.—The climate is mild and pleasant, without being enervating. Situated between Rotorua and Auckland, Okoroire is also intermediate in elevation, so that its climate is milder than that of Rotorua but less so than that of Auckland.

Accommodation. — The place consists of one comfortable hotel on the banks of the Waihou River.

The Baths.—These are primitive wooden structures perched precariously on the river bank. Though primitive, they are distinctly pleasant, and the water, clear and limpid and blue, as all these pure siliceous waters are, is most inviting. The baths are piscinæ about ten feet square, while one, the "Fairy Bath," is an open-air structure built in a spring and overhung by ferns and shrubs.

The Waters. — The most noticeable ingredient of the

waters is sodium silicate. This imparts a characteristic appearance to the water and renders it soft and pleasant in a bath. Internally these waters are used as a general flush to the system.

ANALYSIS

| | Grains per gallon. |
|---------------------------|--------------------|
| Sodium chloride | 17.18 |
| Silicates | 9.70 |
| Total solids | 42.34 |
| Temperature | 113° F. |

Indications.—Okoroire, with its pleasant mild climate and simple baths, its pretty trout stream, and its golf links, is a place for the quiet holiday-seeker rather than the true invalid. At the same time, *mild arthritic cases* undoubtedly benefit, and cases of *chronic gastric catarrh* may do better than at a more potent spring. For the latter cases a tumblerful of the water should be drunk fresh and hot from the spring on an empty stomach. The warm bland fluid will flush the stomach and bowel, while the silicate will exert a very mild antiseptic action.

MATAMATA

This place can hardly at present by any stretch of language be dignified with the name of a spa. A few miles distant from Okoroire, on the same line of railway, it has closely similar springs, but with the chloride of sodium replaced by the bicarbonate. The simple immersion baths are a good deal used locally, but are practically unknown outside the district.

The water should be a pleasant corrective in chronic dyspepsia, and, if drunk in large quantities, an alkaline flush of the urinary system.

ANALYSIS

| | (i) Grains per gallon. | (ii) Grains per gallon. |
|--|---------------------------|----------------------------|
| Sodium bicarbonate | 28.10 | 31.29 |
| Total solids (chiefly silicates) | 46.66 | 48.16 |
| Temperature | 106° F. | 110° F. |

WAINGARO

Waingaro,¹ on the coach-road from Ngaruawahia¹ to the west coast, has waters of the most strictly simple "thermal" type, containing only 22 grains of solids to the gallon. It is not a "spa," though it is used locally and had at one time a great reputation among the Maoris. The outflow of water is very large and the temperature high. There is a large simple immersion bath, with hotel accommodation alongside.

ANALYSIS

| | Grains per gallon. |
|---------------------------|--------------------|
| Sodium chloride | 6.43 |
| Silica | 7.80 |
| Total solids | 22.66 |
| Temperature | 130° F. |

¹ For the uninitiated, the pronunciation of these two places is roughly Wynarrow and Nah-rua-waheah, with an emphasis on the "wah."

CHAPTER XI

CLASSIFICATION OF THE " RHEUMATIC " DISEASES

Classification of Diseases adopted here. — Before making recommendations for sending to specified spas patients suffering from certain specified ailments, it is necessary to define our terminology, for, unhappily, in no branch of medicine is there more confusion of nomenclature than in the so-called " rheumatic " diseases. Thus under the head of " chronic rheumatism " are included a whole series of complaints whose ætiology and pathology are wholly diverse, so that the term is so comprehensive as to be meaningless. Yet, while not official, the word is so universally used that it cannot be ignored.

Again, to half our readers the term " rheumatoid arthritis " will signify an infective polyarthritis, while the other half will regard it as synonymous with osteo-arthritis.

The classification used in this book is based on the author's own experience, and may not be accepted by perhaps a considerable proportion of his readers. It is based, however, on the experience of many years and of many thousands of cases, and at any rate has the merit of sufficient precision to enable the reader to translate the terms into those of the classification to which he is accustomed. It will be noted that the so-called rheumatic diseases are divided into two main groups—those in which the temporo-maxillary and cervical vertebral joints are affected, and those in which they are not. The distinction, although at first sight apparently trivial and arbitrary, is in reality of great practical importance, both from the point of view of diagnosis and of treatment ; for the former class definitely and absolutely excludes gout and true rheumatism, and includes the infective cases, and moreover indicates a tonic line of treatment.

In the subjoined table such conditions as the tubercular, pyæmic, and Charcot joint are omitted, and only those implied by the ordinary use of the term "rheumatic" are included.

SUGGESTED CLASSIFICATION OF THE "RHEUMATIC" GROUP OF ARTHRITIC DISEASES

| | | |
|---|---|--------------------------------------|
| Group A. Jaw-neck syndrome absent. | $\left\{ \begin{array}{l} 1. \text{ Gout (Acute)} \\ \quad \quad \quad \text{,, (Chronic)} \\ 2. \text{ Rheumatism (Acute)} \\ \quad \quad \quad \text{,, (Chronic)} \end{array} \right.$ | |
| Group B. Jaw-neck syndrome present. The toxic and infective group. | $\left\{ \begin{array}{l} 3. \text{ Gonorrhœal arthritis or rheuma-} \\ \quad \quad \quad \text{tism.} \\ 4. \text{ Dysenteric arthritis or rheuma-} \\ \quad \quad \quad \text{tism.} \\ 5. \text{ Toxic arthritis or rheumatism.} \\ 6. \text{ Rheumatoid arthritis.} \\ 7. \text{ Arthritis following acute specific} \\ \quad \quad \quad \text{fevers, e.g. measles, scarlet} \\ \quad \quad \quad \text{fever, enteric, mumps, in-} \\ \quad \quad \quad \text{fluenza.} \\ 8. (?) \text{ Thyroid arthritis or rheu-} \\ \quad \quad \quad \text{matism} \end{array} \right.$ | Group D. 10. Osteo- arthritis. |
| Group C (not rheumatic) | 9. Traumatic arthritis. | |

Of these conditions some are comparatively rare. Gonorrhœal arthritis—a bad name, for it is much more than an arthritis, though gonorrhœal rheumatism is worse—is exceedingly common, though it is not uncommonly overlooked. A slight attack may occur early after infection and pass unnoticed, and yet the disease may be troublesome ten or twenty years later, when the gonorrhœa has been forgotten. Post-dysenteric arthritis is also quite a common complaint.

Arthritis may be associated intimately with hyperthyroidism, and in some cases it would really appear as if the thyroid poison were the actual cause of the arthritis.

Whether arthritis due to hyperthyroidism is uncommon or not the present writer cannot state, as it is not a generally

recognized condition,¹ and may have been overlooked, but he saw two cases during his last six months at Rotorua which appeared to be of this origin or in which at any rate the thyroid condition influenced the arthritis profoundly. The clinical history of the last case is as under.

Hyperthyroid Arthritis (?).—Miss M., aged 18. Father definitely gouty. No previous acute rheumatism. Trouble started gradually in left forefinger from no apparent cause: a few months ago the right knee became affected. On examination, October 1918, there was considerable swelling and soft thickening of the metacarpo-phalangeal joint of the left forefinger; pulpy swelling of the right knee and toes and ankles of both feet; *temporo-maxillary joints* and back of neck painful. The joints did not grate, but were painful, especially with changes of weather. There was a slight soft goitre. Lungs normal. Heart: dulness and sounds normal, but some tachycardia. X-ray of joints negative. As the jaws and back of neck were affected, I was convinced that the case was not rheumatic, and the X-ray negatived acute rheumatoid arthritis. The patient was under observation for a prolonged period, and I exhausted my ingenuity in treatment. Baths, massage, aspirin, oil of wintergreen, were absolutely ineffectual. In view of the family history, colchicum was tried, with a like result. Beginning to suspect the thyroid, I applied an ice-bag² to the goitre, with no effect. The patient went home and returned for a further course in April 1919. The joint condition was worse, the general health excellent, but the pulse was 96, and the systolic blood pressure 110-115 min. Still suspecting the thyroid, oleate of iodine was applied cautiously to the joints, but with no result. Bearing in mind the occasional beneficial results of suprarenal extract³ in

¹ Cf. "Hyperthyroidism and Rheumatism," Poynton, *B.M.J.*, March 29, 1919. The connexion between Graves' disease and rheumatoid arthritis has long been noted, cf. Llewellyn Jones, *Arthritis Deformans*.

² The other case cleared up promptly with applications of ice to the thyroid when all other measures failed.

³ Theoretically of course adrenalin should be contra-indicated in hyperthyroidism.

exophthalmic goitre, adrenalin 10-15 minims 1 in 2,000 solution was then given twice a day on the mucous membrane of the lip. On May 2 the joints were much better, the pulse had fallen to 80, the blood pressure remained unaltered. On May 17, when last I saw the patient before leaving New Zealand, the joints were very much better, the pulse 72, and the blood pressure still unaltered.

Acute Rheumatism.—An acute specific disease, almost certainly due to invasion by micro-organisms. The limb joints are most frequently affected, but *not* usually the temporo-maxillary joints or the cervical spine. As there is practically no controversy about the classification of this disease, we can omit discussion of its other characteristics, such as endocarditis.

Chronic Rheumatism.—Personally, if I make a diagnosis of chronic rheumatism, it is usually with a query and an apology to myself for having failed to make a diagnosis at all. There are cases with antecedent acute rheumatism that appear fairly to deserve this title, but they are vastly outnumbered by those of whose ætiology we are ignorant.

Fibrositis is a symptom and not a disease, and may be due to gout, rheumatism, auto-intoxication, or any of a dozen toxæmias. It is roughly equivalent to the term "muscular rheumatism."

Gout, which may be acute or chronic, is an intoxication with certain products of proteid metabolism, with the possible rôle of micro-organisms still in dispute; but as its place in classification is fairly stable, there is no need to discuss its problems here.

Rheumatoid Arthritis.—A subacute to acute infection, the actual micro-organism being still a matter of dispute. It is characterized by selection of sex, age, and joints, by profound trophic disturbances, while the X-ray picture is distinctive. Thus it is commonest in women, either young or at the climacteric; it causes a soft spindle swelling, peri-articular and articular, of the middle joints of the fingers and of the wrists, but less often of the thumbs, and,



FIG. 82.—THE HANDS IN TYPICAL RHEUMATOID ARTHRITIS.



FIG. 83.—X-RAY OF HAND IN AN ACUTE CASE OF RHEUMATOID ARTHRITIS.



FIG. 84.—SPUR FROM THE OS CALCIS IN GONORRHEAL ARTHRITIS.
In this instance there was a similar spur on the other foot, and both spurs were removed by operation.

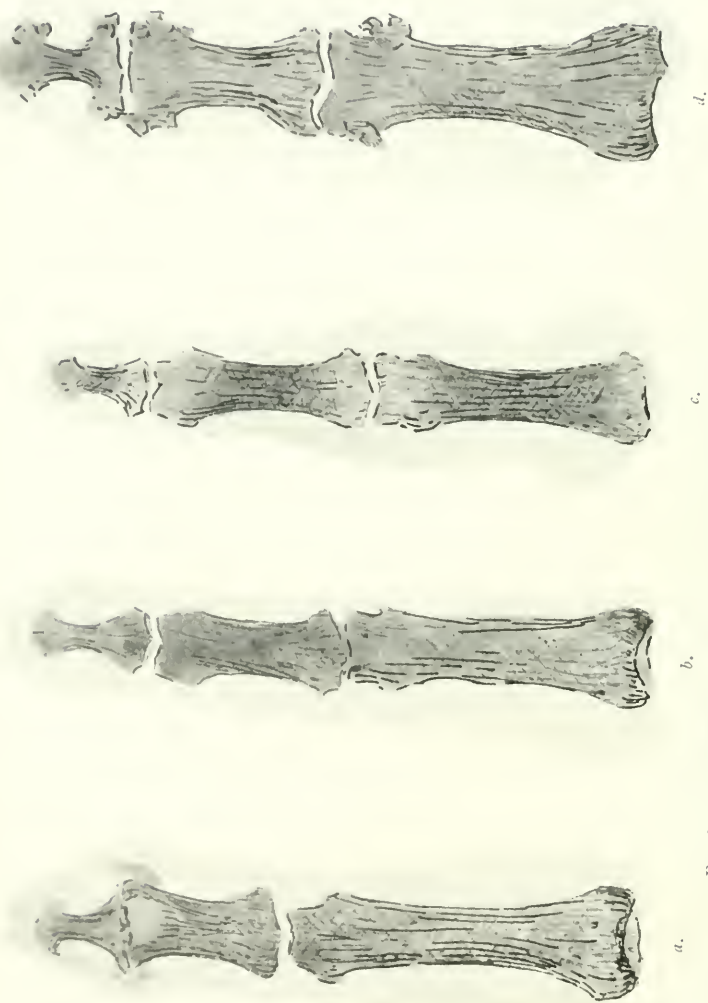


FIG. 85.—DIAGRAM OF CHARACTERISTIC X-RAY PICTURES OF FINGERS IN—
 (a) *Gout*.—*Lacuna* in bone : uratic masses outside the joint throw a faint shadow from commencing calcareous deposit.
 (b) *Gonorrhoical Arthritis*.—No invariable pathognomonic appearance, but condition here depicted not uncommon, viz. obliteration of the first interphalangeal space due to degeneration and atrophy of articular cartilages.
 (c) *Rheumatoid Arthritis*.—Translucency of ends of phalanges in the neighbourhood of affected joints, due to atrophic changes.
 (d) *Osteo-arthritis*.—Fungating masses of exostoses : striation of the bone abnormally distinct ; outlines hard.

whatever other joints are affected, it *always* attacks either the temporo-maxillary joints or the back of the neck, or both. This selection of the jaws and neck is absolutely characteristic of the toxic and infective arthritides, except acute rheumatism. The X-ray picture of a hand shows typical rarefaction of the ends of the phalanges at the interphalangeal joints (vide fig. 83).

Gonorrhœal Arthritis.—In addition to large joints, such as the knee, there is selection of the jaws and back of the neck in nearly every case. There is a tendency to the formation of spurs from the os calcis into the plantar fascia, which is characteristic though not pathognomonic (fig. 84). The clinical picture of the hands may be indistinguishable sometimes from that of acute rheumatoid arthritis, but the X-ray picture is very different. As a rule the bones look normal, but in quite a large proportion of the cases there is a characteristic apparent obliteration of the interphalangeal joint cavity, generally in one finger only. This obliteration is not due to ankylosis, for the joint may be quite flexible, nor is it proportionate to the severity of the arthritis. It would appear to be due to atrophy of the articular cartilages, and though of course such atrophy may occur in other forms of arthritis, its appearance in the finger is suggestive (vide diagram, fig. 85).

Fibrositis, bursitis, etc., are frequent concomitant symptoms, and there is often, a characteristic careworn facies.

Dysenteric Arthritis. — This, like all the other toxic arthritides, affects the jaw and back of neck in nearly every case. Clinically it is indistinguishable from gonorrhœal arthritis, and is equally difficult to treat, but apparently it never causes a plantar spur as does gonorrhœa, nor does the X-ray picture so frequently show apparent joint obliteration. I first came across and described three cases of this condition in 1904, when dysentery was endemic, and occasionally epidemic, in Rotorua. With a new water supply it almost disappeared. Occasional cases of dysenteric arthritis cropped up at long intervals, but on the return of the troops

invalided from Gallipoli, where dysentery was rampant, dysenteric arthritis became one of the commonest complaints we had to treat. The disease appears to be a toxic arthritis due to bacillary infection, either primary or secondary to amœbic dysentery, and, as in the case of gonorrhœal arthritis, it is probable that there is often a mixed infection.

Scarlatina, Measles, Mumps, Influenza, Enteric.—A few cases of arthritis consequent on all these infections are seen from time to time at Rotorua. The description of gonorrhœal or dysenteric arthritis would apply roughly to all of them, and *in every case* that I have seen there was involvement of the temporo-maxillary joints or the back of the neck, or both. In no case, however, did I find a plantar spur or an altered X-ray picture.

It will be seen, then, that *if a case has the jaws and neck affected one can pretty confidently assert that it is neither rheumatic nor gouty.*

Traumatic Arthritis is generally monarticular, and, like occupational arthritis, which is really only a sub-class of traumatic arthritis, and which is often polyarticular, tends rapidly to pass into osteo-arthritis.

Tubercular Arthritis hardly comes within the scope of our present discussion.

Osteo-arthritis I regard as a "mechanical" condition, the common end to which all cases of arthritis, with the exception of such things as tubercle and pyæmia, tend; as an effort of Nature, somewhat misguided if you will, to effect a cure. I would sharply define this condition, with its eburnation and its callus-suggesting exostoses, produced in obedience to obvious mechanical laws, from rheumatoid arthritis, which is a *destructive* and not a *constructive* process. In any joint that has been seriously damaged, whether by gout, rheumatism, injury, or occupation, which latter is only another way of putting "repeated small injuries in one direction," osteo-arthritis is the eventual result. In occupational arthritis the form of the resultant osteo-arthritis depends upon the nature of the occupation,

and may be foretold ; or, conversely, the nature of a man's occupation may sometimes be deduced from the post-mortem examination of his joints. The amount of new bone formation would appear to be an index of the vitality and reactive power of the individual.¹

If this scheme of classification be adopted, at any rate provisionally, it will be found that there are fewer cases about which one is seriously in doubt as to diagnosis.

Thus a doubtful case will be, as a rule, either gouty or rheumatic, or one of the toxic group. If the jaws and back of the neck are affected, it is practically certain to be a toxic case, and ninety-nine times out of a hundred either rheumatoid or gonorrhœal. The former may be distinguished by the general clinical picture and by the atrophic thinned bone-ends in the X-ray picture, the latter by the history and, sometimes, by the appearance of a pseudo-ankylosis of a finger in the X-ray picture or the occasional detection of a plantar spur, or finally, and this a by no means decisive test, reaction to vaccine.

Further, it will be found a good general rule that all those cases in which the temporo-maxillary joint is affected—that is, all toxic cases—require essentially *tonic* treatment : fresh air, sunshine, abundant good food, tonic waters, tonic baths, and tonic medicines.

¹ Sir Arbuthnot Lane.

CHAPTER XII

SPAS SUITABLE FOR INDIVIDUAL CASES

It would be exceedingly convenient if a table could be drawn up showing what spa, what water, what particular bath, is indicated in such-and-such a complaint, exceedingly convenient, but, except on broad lines and with many reservations, impossible.

The general indications for, and general scope of, spa treatment are elsewhere touched on (p. 225). Mineral-water treatment affords a reasonable hope, when often there is no other hope, of breaking the vicious circle of disordered metabolism, and may be utilized as a *preventive measure* in cases in which, while there are departures from the normal in the matter of function, actual organic changes are not yet discernible; it is indicated as a *remedial, arresting, or corrective measure* during the course of chronic disease, in which, while organic changes have taken place, yet the machine is not so far crippled that it may not again be made to work with reasonable smoothness; and, finally, in the late stages of chronic disease, when organic changes have so far progressed that repair is hopeless, it may be used as a *sedative measure*, may soothe pain, diminish stiffness, promote general comfort, and, in a word, render tolerable an existence which has become almost intolerable.

It is necessary, however, even at the risk of seeming dogmatism, to leave the vague region of generalities, and to be as explicit as the nature of our subject, chronic disease, will permit, merely accentuating once again the point that, while we are forced to label our patient with the name of a disease, it is the patient that we have to treat,

the patient with his own microcosm of idiosyncrasies, physical and psychical, and not the disease.

Gout.—Cases of gout in the acute stage, or with an acute attack immediately threatening, should not be sent to a spa. For some weeks after an attack, the time varying with the individual, the patient should be treated on ordinary medical lines, and he should rather be *prepared* for a course of mineral waters. As already pointed out, a course of baths and waters tends to cause an initial exacerbation of symptoms in most diseases, and this is especially true of gout.

The “old-fashioned” kind of gout of which one saw so much in England twenty or thirty years ago, and of which one sees so little in New Zealand, with great tophaceous masses, and fulminating attacks in the joints, requires wholly different handling from the kind more often seen now.

It is convenient therefore to divide, for purposes of treatment, cases of gout into two main groups:

(a) The sthenic, plethoric group. This type is familiar: the patient is generally a man of middle age, robust, and often stout, who has “lived well,” eaten and drunk heartily, has had periodic attacks of acute gout in the great toes, the fingers, or the elbows, with a vigorous and perhaps open-air life in between.

Such a patient, put without precautions straight on to full balneological treatment, is pretty sure to get an acute attack within the first week. He requires dieting and purgative waters, and unfortunately it is in good purgative waters that New Zealand is most deficient.

The best plan is to send him, after preliminary treatment, to TE AROHA, there to start with graduated doses of the cold magnesia waters, followed after a week, if the gout remains quiescent, with a graduated course of the thermal alkaline waters from Spring No. 8 or No. 15, combined with subthermal baths (93°–95° F.). Later he may venture into a more stimulating bath, such as No. 2, and finally, and if necessary, proceed to ROTORUA. Here again he

must "feel his way," taking warm baths at first rather than hot, and drinking either Te Aroha or Rachel water, unless the latter causes indigestion. He should avoid too vigorous measures, and if any massage is used it should be gentle and sedative.

Such cases also do well at KAMO. Here the same pre-



FIG. 86.—TOPHACEOUS MASSES IN THE HAND OF A MAORI.

cautions should be adopted in starting the course, and, as the waters are diuretic and not purgative, saline aperients should be taken in addition. The subthermal effervescing bath is of course very much more stimulating than the baths at Te Aroha, and needs to be taken with the greater caution.

Cases requiring a mild and sedative climate, especially, for instance, those with a tendency to asthma and bronchitis,

may with advantage be sent to WAIWERA or HELENSVILLE, both of which have saline waters. The former has the advantage of most charming surroundings, but the disadvantages of no railway and no resident doctor.

While dealing with the subject of acquired plethoric gout, it is an interesting point to observe how rare acute and tophaceous gout is amongst the Maori race, although the scourge is by no means unmerited in many instances. I have, however, seen one or two cases (vide fig. 86).

(b) Asthenic gout. This is much more common in New Zealand, and is almost as common in women as in men. There is generally a family history of gout, and the sufferer is frequently dyspeptic. Attacks are subacute only, and there is a greater tendency to chronic ill-health and to manifestations of gout in situations other than joints and bursæ. Beyond an excessive consumption of meat, tea, and sweets, a universal sin in New Zealand, the disease is the misfortune rather than the fault of the patient, and as regards alcohol the majority of the sufferers are teetotalers.

Such cases require wholly different treatment from the plethoric type. The diet should be generous, but with due regard to the digestion, and alcohol is not necessarily forbidden; fresh air, sunshine, and cheerful but restful surroundings should be part of the spa treatment, and sulphur waters are especially indicated.

Such cases do well at ROTORUA, taking a course of baths cautiously increased in strength, e.g. Rachel at body temperature, followed by Old Priest if weather permits, New Priest, Aix, and finally Postmaster; but each case has to be graduated according to individual reaction.

In regard to drinking the waters, if the Rachel water agrees, it should be started in small doses, and gradually increased; if it disagrees, then Te Aroha water may be substituted.

Some cases do well with the carbonated mild chalybeate waters of KAMO.

Rheumatism.—There is probably no mineral spring in

the civilized world, and certainly no thermal spring, which has not at some time or other been esteemed as "good for rheumatism." In a sense the claim is justifiable, for, in view of the loose manner in which the term "rheumatism" is used, not only by the public, but even by ourselves, it means no more than a remark that vague chronic pains of ill-defined origin are benefited by balneological treatment. It behoves us, therefore, to define our terms and to clarify our conception of rheumatism (cf. p. 140).

We are all agreed as to the clinical meaning of acute rheumatism or rheumatic fever, though by no means so agreed as to its ætiology. Assuming, however, the disease to be due to an invasion by micro-organisms,¹ it is obviously impossible to separate the milder infection of a subacute attack from the acute specific fever. On the other hand, it is sometimes exceedingly difficult to differentiate between a subacute attack due to rheumatic and to other toxins. The test of reaction to salicylates is of very doubtful value, as symptoms of most varied origin are relieved by the same drug, and the test of reaction to vaccines is by no means certain. In subacute and chronic cases we are driven at present to rely chiefly on the clinical picture, and more especially on the election of certain joints by toxins, and the X-ray appearances (vide fig. 85).

Under acute rheumatism, then, we include subacute attacks and the very atypical attacks that occur in childhood, but which nevertheless cause endocarditis. All such cases are, during the attack, of course unfit for any spa treatment.

Convalescence from Acute Rheumatism.—At this stage, however, balneological treatment may do immense good. Indeed, I have found such cases amongst the most satisfactory of all the many thousands that passed through our hands at Rotorua, provided that at least a month were permitted to elapse between the last rise of temperature

¹ Poynton and Paine, *Streptococcus Rheumaticus*. For a complete bibliography of the subject see *Guy's Hospital Reports*, vol. 45, p. 193 (Sandison).

and the commencement of treatment. The principal complicating factor is the presence of endocarditis, and when this is recent, and coupled with anæmia, balneological treatment is contra-indicated, though spa treatment is not.

Such cases improve wonderfully with change of environment, and especially with a dry sunny climate, but require careful medical supervision. Thus the choice of a spa will depend partly on the time of year and partly on the necessary factor of medical attendance. It is not safe to send such patients to a spot, otherwise suitable, but too far from a doctor to make medical supervision effectual. On the whole, either ROTORUA or HANMER is to be recommended, except in the winter, when Hanmer may be too cold for a patient unable to take vigorous exercise. Cases in which the anæmia is the most prominent feature will do well at KAMO, but special arrangements must here be made for medical attendance; and if baths are given, very special precautions must be taken (*vide* Kamo, p. 130).

Ordinary cases of convalescence from rheumatic fever, with perhaps a slight mitral murmur and good compensation, may be sent to ROTORUA with every confidence, provided that they are put strictly into the doctor's hands and not allowed, as so many do, to treat themselves. A graduated course, beginning with small doses of Rachel water and, in summer, the subthermal effervescent Priest bath, with an open-air life, regulated exercise, and a generous diet, will improve the condition in a most gratifying manner. The effect of hot acid baths in improving the blood content has been already noted (page 79).

Chronic Rheumatism.—This term is so universal that it cannot well be omitted from a useful list, but at the same time is so abused that one hesitates to use it at all. The term is here used to indicate a chronic or recurrent arthritis, fibrositis, or bursitis in patients who have at one time had acute rheumatism or who have a strongly rheumatic family history. Such cases do well at almost any spa, especially those in which hot stimulating baths are available. Thus

they may be sent to HANMER, TE AROHA, HELENSVILLE, TE PUIA, or MORERE, or may take the hot piscinæ of TAUPO or WAIRAKEI, but the place *par excellence* for them is ROTORUA, and, if they can stand it, the Postmaster bath. Later they will probably benefit by the Aix douche.

Lumbago and Sciatica.—These are obviously symptoms and not diseases, and may or may not be rheumatic or gouty. Both are frequently traumatic, and still more frequently occupational, and both benefit rapidly as a rule by spa treatment. The milder forms may be sent to any of the spas recommended for chronic rheumatism, but many cases, especially of sciatica, are extremely obstinate, and require specialized treatment: indeed, I do not know of any class of case about which it is more unsafe to make an early prognosis.

Such patients should be sent to ROTORUA, where not only are there the most potent baths, but where every possible alternative treatment is available. The means usually adopted are the Priest bath with the undercurrent douche, the Postmaster bath, the revulsive douche in the Aix bath, and various electrical treatments, such as the anode along the course of the nerve, fine faradic or sinusoidal currents, as in the electric bath, and counter-irritation by the vacuum electrode of the high-frequency apparatus. In addition, stretching and loosening of adhesions, and sedative massage, as advocated by Mennell, aid, and are aided by baths. The actual line of treatment followed will of course largely depend upon whether the condition is a neuralgia, a neuritis, or a perineuritis.

In definitely gouty cases it may be advisable to send the patient for a course of the waters at TE AROHA.

Neuritis.—This being as a rule a symptom only and the effect of many diverse causes, will require as diverse treatment, but the majority of cases do better under spa treatment than at home.

Our object must be to remove the cause, to ensure rest, and prevent deformity, and, finally, to restore function

both to the nerve and to any muscles it may supply. To attempt the last object before ensuring the preceding ones is only to court failure. The cause may be a mineral poison such as lead, a simple organic chemical poison such as alcohol or tobacco, a toxin such as that of diphtheria or influenza, or it may be traumatic.

Epidemic Neuritis.—During the years 1916–1918 a wave of neuritis in epidemic form spread over the whole of New Zealand. There appeared to be no antecedent specific disease, and the onset was often acute, and generally in one arm. The sufferers, who were of both sexes, but more frequently women, were generally “run down” with anxiety and war-work, and in many instances had done an inordinate amount of knitting; but in many cases there was no discoverable cause whatever, so that, in view of the great number of the cases and their widespread distribution, one was driven to look upon the epidemic as one of acute infective disease. Sometimes a single nerve, such as the ulnar, was alone affected, but more often it was a definitely brachial-plexus neuritis, and occasionally there were symptoms of root lesion. The left arm was affected more often than the right.

Cases of neuritis must be sent to a spa where they can have constant medical supervision, and for this reason ROTORUA is preferable to one of the smaller spas. The essential treatment is rest to the part, e.g. the arm in a broad-arm sling, subthermal baths, and, when available, a diuretic water; so that mild cases may do well at KAMO or WAIWERA. In later stages a more stimulating bath, such as the Priest at ROTORUA, may be substituted, and electrical treatment started. This opens up the whole vexed question of the direct value of electrical treatment on nerve, and the reader is referred to page 259. The value of the counter-irritant use of electricity, for instance in the form of the vacuum electrode, is, however, undoubted, and, in bad motor-nerve cases, prolonged treatment of the muscles with interrupted galvanism or the Bristow battery, according

to the presence or absence of R.D., is almost essential: again, pain may be relieved by ionization.

At quite an early stage very gentle and sedative effleurage may be used with advantage, but on no account whatever must such cases be sent to a masseur with the simple direction that they are "to have massage." In no cases that come to a spa is there more urgent need for experienced and skilled medical supervision.

Neuralgia.—In cases in which the medical attendant has satisfied himself that there is no organic cause, the patient may be sent to a bracing upland place, such as TAUPO or WAIRAKEI or HANMER, being merely cautioned to avoid excess of hot baths. The open-air life, sunshine, and interesting thermal "sights" may do the rest. If this fails, the patient should go to ROTORUA for special treatment, generally electric counter-irritation and soothing applications, such as mud baths or cool low-pressure douches. Some cases derive most benefit from cold applications, such as a cold douche to the spine, or the Scotch douche; others, however, are wholly unable to bear cold. I have seen sometimes great benefit result from a filiform douche along the course of the nerve.

Cases of causalgia, with which we have unfortunately become familiar as the result of gunshot wound of nerve, are exacerbated by hot baths and require subthermal or even cold-water treatment.

Hysteria.—The treatment of this condition is of course psychic, and the suggestive influence of spa treatment is a powerful aid. Such measures as the Scotch douche at ROTORUA or electrical treatment are also available, but it must be remembered that more depends upon the doctor wielding the instrument than on the instrument itself, and there is a danger, especially amongst self-treating patients, of spa treatment welding their fetters yet more firmly.

Neurasthenia.—Spa treatment is particularly valuable. The change of environment, the change of habit of living, and the mere rest, apart from all treatment, may alone

effect a cure. One has to be careful, however, that the provocative cause is not carried with him by the patient to his new surrounding. Mild cases may be sent to the cool effervescing baths at KAMO, but most, as a rule, will do better at a spa where there is more to see and more going on, such as ROTORUA. The treatment there for cases that require stimulation is the Scotch douche and various electrical applications, or, for those needing more sedative treatment, the subthermal Old Priest bath or the electric bath. In either case hot baths should be used with caution, and cool applications are more often indicated.

Mild cases may do better with climatic treatment, either a completely sedative resort such as WAIWERA or a stimulating one such as TAUPO, HANMER, or, better still, MT. COOK.

Insomnia.—Here we have first to determine the cause, and spa treatment may or may not be indicated. It is no use sending a patient with insomnia and high blood-pressure due to tobacco to take a course of waters if he also takes his pipe with him. Many cases, however, do improve with subthermal baths and a course of eliminative waters, such as KAMO, or the Old Priest bath at ROTORUA; while others do better with a sedative station such as WAIWERA, HELENSVILLE, or TE AROHA. Should there be definite high blood-pressure and no organic disease, the patient should be sent to ROTORUA for special treatment of that condition (vide p. 155).

Organic Disease of the Nervous System.—Cases of central organic disease that can reasonably be expected to improve with spa treatment are obviously comparatively few, but still there is more to be done than would at first sight be expected. Treatment lies in two directions: it can be prophylactic or it can be compensatory. The former treatment resolves itself into measures designed to avoid a repetition of disaster; thus, in a case of cerebral hæmorrhage it means reduction of blood-pressure and elimination of toxins: the latter means education of other muscles

or groups of muscles to compensate for those lost, together with, when possible, the recuperation of paresed muscles.

Such treatment demands not only a suitable spa, but a specially equipped establishment of doctor, attendants, and appliances, and cases needing it should therefore be sent to ROTORUA.

Hemiplegia.—Such cases, especially if due to hæmorrhage, should not be sent until from one to three months after the stroke. They are given subthermal baths, with special precautions against hurry, bustle, and worry, both in and after the bath. Diet and habits are attended to, and gentle massage and electrical treatment may be added. If the blood-pressure be high, attempt is made to reduce it in the manner stated below.

Locomotor Ataxia and other Spinal Paralyses.—We have here an example of compensatory treatment.

In these cases not only may lightning pains and crises be relieved by subthermal baths, but there are often long periods during which the disease appears to be at a stand-still, and these periods may be utilized in re-educating the muscles of the lower limbs by exercises teaching co-ordination. Such exercises need great patience and intelligence on the part of the instructor as well as perseverance on the part of the patient: the results, however, are often surprisingly good. One little practical point I would like to bring forward. If the patient in ordinary life will carry a heavy walking-stick horizontally in two hands like a balancing-pole, he will greatly lessen his ataxia, and the position is not very conspicuous. By so doing he may get balancing sense through spinal centres above his lesion. Treatment at present can only be obtained at ROTORUA.

Vaso-motor Disturbances.—Cold extremities, chilblains, and mild Raynaud's disease benefit from the use of the Priest and Postmaster baths at ROTORUA. These are used hot to the body generally, and, in addition, the hottest Postmaster bath (109°–112° F.) may be ordered locally. Massage, especially faradic massage, is used as an adjunct.

High Blood-pressure.—I have seen the systolic pressure fall steadily under a course of combined high-frequency current and radium-emanation water, often from 200 or 230 mm. to 160 or 180. ROTORUA is the only spa in New Zealand at which this treatment can be followed. Diet and regulation of habits must of course also be attended to, sub-thermal baths of prolonged duration given, and perhaps footbaths in the hottest Postmaster bath.

Cases of early arterio-sclerosis with hyper-tonus, of the plethoric type, might take the waters at TE AROHA, but avoiding the hot baths; while the spare dyspeptic type would benefit by WAIWERA or HELENSVILLE.

Low Blood-pressure, and Hypo-tonus.—Comparatively cool baths should be given, such as the effervescing Priest baths at ROTORUA or the natural bath at KAMO, while the circulation should be encouraged by massage and stimulating douches.

Heart Disease.—In cases of insufficient compensation, with flabby heart muscle, improvement may often be obtained by some form of Nauheim treatment. In this the "skin heart" (vide p. 250) is stimulated by effervescing baths, and graduated resistance exercises are given. These baths, in somewhat attenuated form, can be given at ROTORUA in the old Priest bath, while the exercises are part of the usual routine there. Much better results should be obtained at KAMO, whose waters are ideal for the purpose, but it would not be safe to send such patients there in the present state of the spa's development. It need hardly be added that no cases that have recently suffered from endocarditis should take spa treatment.

Glycosuria.—Cases of true diabetes are, as a rule, unlikely, especially in young subjects, to benefit by mineral-water treatment; but those of gouty glycosuria do well at TE AROHA, provided that they are under proper supervision as to diet. A certain proportion of glycosurics, and even of true diabetic patients, appear to benefit in marvellous fashion from drinking radium-emanation water; this can be obtained at ROTORUA.

Dyspepsia.—Patients suffering from dyspepsia, the result of too much and too pungent food and drink, require a spa where can be combined a purgative water, exercise, and dieting ; in such resorts New Zealand is unhappily lacking. On the whole they are best sent to ROTORUA for douche massage and a regulation of diet to which they will perhaps not submit at home.

Obese and congested subjects, especially if with hyperacidity, should go to TE AROHA. For the thin, nervous, atonic dyspeptic with hypo-acidity the waters of KAMO or WAIWERA may be advised.

Obesity.—The florid, plethoric obese may be benefited by TE AROHA, with of course diet and exercise ; the anæmic, atonic obese would do better with the baths of KAMO, when these are made safer than at present. In the meantime, massage and cool douches at ROTORUA, followed perhaps by the use of the Bergonié apparatus there, would be the best that can be done. I have, however, seen most extraordinary reductions of weight take place from a course of mud baths at Rotorua. All hyperthermal measures for the treatment of obesity should, however, be followed by cold applications.

Constipation.—As already noted, there are no true purgative waters in New Zealand.¹ Mild, laxative magnesium bicarbonate waters, however, may be obtained at TE AROHA, and there is a pleasant, cool magnesia spring at present in private hands at PAEROA. Constipation with atonic dyspepsia may also be relieved by the saline waters of WAIWERA or HELENSVILLE.

More serious cases, however, can be treated at ROTORUA. Thus atonic cases should take the subthermal Old Priest bath, cold Sitz baths, the Aix douche, massage, and electrical treatment of the abdomen, and the special exercises for

¹ The Okain's Bay water from Banks' Peninsula is a strongly purgative magnesium chloride water, but is practically useless on account of the huge amount it contains of calcium and iron salts. There are also mild, laxative magnesium waters around Lyttelton Harbour.

constipation, with of course dieting. Others, in which there is fullness and irritation of the colon, may be treated at ROTORUA by the Plombières douche, followed by a sedative bath and the submassive douche to the abdomen.

Biliary Calculus.—Mild cases may do well at TE AROHA, and nearly all cases *after* operation are benefited by a course of these alkaline waters (cf. p. 117). Cases of chronic hepatic derangement, with a tendency to constipation and slight jaundice, should take the cold magnesia waters from No. 21 Spring.

Renal Calculus.—As stone in the kidney consists as a rule principally of calcium oxalate or phosphate, alkaline waters are contra-indicated (cf. p. 117), but the diuretic waters of KAMO, taken very freely, may well be beneficial in some cases.

Vesical Calculus.—Stone in the bladder may consist of almost pure uric acid, and here the alkaline waters of TE AROHA may be most strongly recommended. Cases of cystitis with alkaline urine should, however, avoid Te Aroha and go to KAMO.

Nephritis.—Cases of early nephritis may benefit by spa treatment. They require a mild sedative climate, and should avoid sodium chloride waters, taking rather sulphide or calcium waters, and warm rather than hot baths. In the summer they may besent to ROTORUA, but, unless the weather is warm, KAMO would be more suitable at other seasons, with a warmer and more equable climate and calcium waters.

Syphilis.—Sulphur waters are said to increase the intensive action of mercury, and a few cases of syphilis are therefore from time to time sent to ROTORUA. The action of sulphur, in spite of the undoubtedly deserved reputation of Aix-la-Chapelle, is in this matter still *sub judice* (cf. p. 71).

Anæmia.—Cases of simple anæmia and chlorosis may be treated by the administration of chalybeate waters by the mouth, or by tonic baths, or by both. Thus KAMO offers mild chalybeate waters combined with powerfully stimulating carbonic acid baths, and, with due precautions as to

bathing, is eminently suitable, if combined with laxatives. *The cold springs at TE AROHA*, those situated outside the public gardens, contain ferrous bicarbonate in varying amounts up to 4·5 grains per gallon, and a considerable amount of free carbonic acid. In anæmic cases, however, the hotter baths should, as a rule, be avoided, and the patient should take only brief immersion in one of the cooler "natural" baths. There are numerous other chalybeate springs in New Zealand, some of them of great strength, but, as a rule, either the iron is not present in an easily assimilated form, or no provision is made on the spot for invalids. For reasons already given, many cases improve wonderfully with a course of the cool effervescent Priest bath at ROTORUA.

Eczema.—Water is said to be bad for eczema, and the direction is frequently given to avoid washing as much as possible. The statement is, I believe, misleading, as it is only a half-truth. Water, as ordinarily applied, quite undoubtedly does harm to the eczematous skin, but it is not the wetting but the subsequent *drying*, especially drying by evaporation, that does the mischief. Prolonged immersion in water, especially a bland mineral water such as the alkaline siliceous Rachel water at ROTORUA at the indifferent temperature, will frequently do immense good, if precautions are taken to prevent the skin from getting too dry after the bath. The plan I adopted was, for dry cases, to use a few drops of Liq. Carbonis Detergens 1 in 4 of glycerine, poured into the palm of the hand, and gently rubbed over the whole wet skin on coming out of the bath. The skin could then be wiped in the ordinary way, but sufficient medicament would adhere to prevent the dry and cracking sensation usually experienced after washing. In more acute cases the mud bath was used, and allowed if possible to dry on in a thin protective film, or the Rachel bath followed by a suitable ointment. All applications to the skin act more effectively after it has been softened by a warm bland bath. Other cases, especially seborrhœic

cases, do better with the warm baths at TE AROHA. Of course it is necessary to treat at the same time any constitutional underlying cause such as gout, constipation, or toxæmia, and sulphur waters internally are often indicated.

Psoriasis.—The same treatment is required as for dry eczema. Of course there are many hopeless failures, but at the same time there are many more successes, and ROTORUA should certainly be tried. Hotter baths may be employed than in the case of eczema.

Acne, Furunculosis.—Sulphur waters externally and internally are universally recommended, and patients may accordingly be sent to ROTORUA. My experience, however, of such cases is that sulphur waters are of little use. Lewis Jones recommended the electric bath in acne, and very many cases were accordingly treated by this method at Rotorua, using Rachel water as a medium, but with only occasional success.

Convalescence from Acute Disease.—These cases as a rule do not require baths and waters, but rather change and a bracing climate. Thus, apart from seaside resorts, MT. COOK, HANMER, MT. EGMONT, TAUPO, or WAIRAKEI are available in the summer. In the winter ROTORUA, WAIRAKEI, and TAUPO are probably the best available spots. If baths are taken they should be tonic and cool, so that, on the whole, the seaside is generally preferable to an inland spa.

Pelvic Conditions.—Dysmenorrhœa and irritable pelvic conditions, menorrhagia with early fibroids, and chronic catarrh and leucorrhœa may be improved by sedative baths and climates, for instance TE AROHA, WAIWERA, or HELENSVILLE.

Traumatism.—Spa treatment in the form of baths, massage, and electricity is invaluable in the after-treatment of numerous injuries. Thus the stiffness and disability remaining after the use of splints, the atrophy of muscles from disuse, strains, sprains, and traumatic arthritis, may

all be better treated at a spa than at home. For such cases a fully equipped spa such as ROTORUA is the place of election. The value of physical treatment in injuries has long been recognized, but it was not until the great war that the full value of such treatment, as exemplified in the case of wounded soldiers, was universally established. Indeed, such treatment is almost in danger of over-popularity, and the impossible is sometimes expected from it.

Senility.—While spa treatment cannot be expected to rejuvenate, it can do a good deal towards removing the causes of premature senility, and so of retarding the process. Thus the skin, like other organs, tends towards glandular atrophy, and its normal excretory function is diminished, with consequent increased retention of toxins and a corresponding increase of stress on the other excretory organs, and on the vascular system.

Again, coincidently with degenerative changes in the blood-vessels there is a similar tendency to changes in the elastic tissues of the skin. Clinically and æsthetically this change is universally recognized and familiar, but I venture to doubt whether its physiological effects have often been considered.

The changes consist essentially of a fibrous degeneration of the minute unstriped muscular bundles of the skin and a replacement of yellow elastic by white fibrous tissue. As a result the elastic support of the cutaneous capillaries is largely lost.

As is noted in Chapter XVI, these small muscles and the meshwork of yellow elastic fibres take the place in the ultimate cutaneous vessels of the muscular and elastic coats of the arteries, and the degeneration of these intercapillary tissues is strictly comparable to the degeneration of arterial walls. Without such elastic peripheral resistance, and with blood pumped into comparatively rigid pipes, the "tone" of the peripheral circulation is impaired, the maintenance of the normal blood-pressure is rendered more difficult, and there are back-pressure effects which react on the

arterial tone and on the heart muscle. In a word, the " skin heart " function is largely abolished. This condition cannot again be restored to the elasticity of youth, but, in the early stages, a course of massage and of alternating hot and cold baths and douches constitutes a measure of skin gymnastics that is materially prophylactic. For such a course ROTORUA or HANMER may be recommended. In more advanced cases a course of baths at about or a little above the indifferent temperature, and with prolonged immersion, followed by rest, will often do much to restore the action of the skin, and to equalize the balance between the deep and superficial circulations, to soothe irritable nerves, and generally to tranquillize and to rest. Quiet, restful surroundings and a mild equable climate are excellent accessory factors, as is also the drinking of eliminative waters. On the whole, it would be difficult to find a place more suitable than WAIWERA. The motto in all such cases should, however, be *festina lente*.

Rheumatoid Arthritis and the jaw-neck syndrome group, including *Gonorrhœal arthritis*, *Dysenteric arthritis*, etc. These cases all require tonic measures ; some may possibly require the simultaneous use of vaccines, and all require close medical supervision. They should therefore be sent either to ROTORUA or HANMER ; to the former at any time of year except perhaps February, to the latter in spring, summer, or autumn, but, as a rule, not in winter. The baths *par excellence* for these conditions are the Old Priest baths and the Postmaster at ROTORUA, with brief immersion.

CHAPTER XIII

CLASSIFICATION AND ANALYSES OF THE MINERAL WATERS

1. Simple Thermal Waters.
2. Muriated Waters: (a) Sodid Muriated; (b) Calcic Sodid Muriated.
3. Iodine Waters.
4. Alkaline Waters: (a) Simple Alkaline; (b) Muriated Alkaline.
5. Magnesium Waters: (a) Alkaline; (b) Muriated; (c) Sulphated.
6. Calcareous Waters.
7. Chalybeate Waters.
8. Sulphur (or Siliceous) Waters: (a) Alkaline; (b) Acid; (c) Muddy.
9. Arsenical Waters.
10. Borated Waters.
11. Table Waters.
12. Mud: (a) Sulphur Siliceous; (b) Mercurial Siliceous.

Geographical Classification.—The different classes of mineral waters have a certain rough general plan of geographical distribution, so that the probable nature of a spring may, to a certain extent, be inferred by its position on the map, though this is a rule with many exceptions, and the point must not be pressed too far.

Thus, in the central pumice plateau of the North Island, from Mount Ruapehu in the south to Rotorua in the north—that is, in other words, in “the thermal district”—the springs are volcanic, and are very hot, sulphuretted, siliceous, and weakly mineralized; in this district too, and more especially in certain islands of the adjacent Bay of Plenty, are found sulphuric acid springs, which in White Island are associated with hydrochloric acid of phenomenal strength.

Along the east coast, from East Cape to Cape Palliser, muriated waters of high specific gravity and containing

iodides predominate. Along the same coast, from the Bay of Plenty northwards, weak saline waters are found; in the lower Waikato valley are chiefly simple thermal waters; in the Thames Valley alkaline bicarbonated waters, both hot and cold; while in the limestone regions of the peninsula north of Auckland are waters, cold or slightly warm, rich in carbonic acid gas.

The South Island is comparatively poor in mineral springs, and these are for the most part simple thermal or feebly saline waters of low specific gravity.

Classification adopted.—At the outset one is met with considerable difficulties in the attempt to classify mineral waters, and whatever system be adopted it is open to serious objections. Until recently waters have generally been classified according to their chemical composition, or perhaps one might say according to their gross chemical composition. This method rests on the assumption that certain ingredients which bulk most largely in the analysis, or which from their therapeutic activity appear of predominating importance, determine the general character of the water in so far as the physician is concerned. Recent research, however, has made us accept this assumption only with grave reservations, and it is realized that other important factors have to be considered.

Bearing in mind, however, the imperfect nature of our knowledge of these new factors, it would seem unsatisfactory and misleading at present to express analyses in terms of ions or electrical conductivity or radio-activity, and ordinary chemical constitution has alone been considered here.¹

¹ The following classified list of waters is based almost entirely on the analyses recorded in the reports of the Dominion Museum and Laboratory published by the New Zealand Government between the years 1902 and 1919, and of these a large proportion of the more important in recent years have been made by Dr. Maclaurin, Dominion Analyst. On account of the space which would be required to give the full detailed analysis of each specimen, only the essential and characteristic ingredients and the total grains per gallon of solid constituents are given here. In all cases,

In a work such as this, intended primarily for the guidance of medical men in actual practice, the essential feature of any system of classification should be its practical utility, and the nomenclature adopted here, while manifestly at best a compromise,¹ is that most familiar to medical men, and at any rate affords a serviceable classification for medical purposes.

In schemes of classification it is difficult to resist the temptation to subdivision, and classes of lithium and of aluminous waters might reasonably have been admitted. While noting the presence of these salts, however, the waters have been classed under the heading of what appeared to be more important ingredients, as in the case of the lithium in the Te Aroha waters, and of the alum in the acid and sulphated waters.

For the sake of comparison, a well-known example of European mineral water is given with each class, except of course in those rare instances in which a New Zealand water has no corresponding European prototype.

CLASS I. SIMPLE THERMAL WATERS

These constitute a somewhat indefinite group of waters characterized by weak mineralization. Obviously it tends to shade off at one extremity into any one of the other

however, in which the analyses have been taken from the above reports the year is also given to facilitate reference should fuller details be required. For further information on this subject the reader is referred to the paper by Mr. W. Skey in the *Transactions of the N.Z. Institute*, 1877, to several published pamphlets by Mr. J. A. Pond, and to the article by the late Sir James Hector in the *Official Year Book*, 1893. The names Skey, Pond, and Hector at the head of an analysis have reference solely to the above-mentioned papers.

¹ Dr. Peale (Cohen's *System of Physiologic Therapeutics*) devised a more accurately descriptive system, theoretically most excellent; but such uncouth strings of adjectives as "carbonated-sulphated-calcic-magnesian-chalybeate" seem too cumbersome for everyday use. The classification adopted by Weber (*Climatotherapy and Balneotherapy*, London, 1907) has been followed here, amplified in the case of unfamiliar indigenous waters by the use of a modification of Peale's system.

groups, so that a particular water may be classified by one authority as "simple thermal," by another as "saline," and so on.

Such waters are largely used both for drinking purposes and as baths. Taken internally they act as depuratives, mechanically flushing out the system, and are indicated in chronic arthritic diseases, more especially when associated with constipation and toxæmia.

It may reasonably be asked why, under such conditions, trouble to go to a spa, why not drink plain water at home? The answer is that "there is a great deal of human nature in man." A patient will readily and conscientiously take a course of such waters at a spa, but by no means can be persuaded to carry out the course systematically at home. In addition of course, and for the same reason, he will consent to a regulation of his diet, and furthermore he will take a simultaneous course of baths.

Such waters, when used as baths, owe their therapeutic value very largely to the hot water as such, and therefore largely to the skill with which they are used; they are in fact useful for all cases that otherwise would be sent to a hydro.

This by no means implies that such baths are of little value. The vast majority of mineral-water baths are efficacious almost entirely in virtue of their hot water; it is only in the minority of waters that the "mineral" factors enter; but, as we have elsewhere shown, the effects of hot water, and especially of "fresh" hot water in unlimited supply, are very considerable.

As a rule such springs yield an abundant supply, and it is a notable fact that in European spas supplied by simple thermal waters the development of systems of douching, and indeed of hydro-therapeutics generally, has reached a high pitch of perfection.

There are, however, other factors, especially when the water is used by the mouth.

Weakly mineralized waters are generally more fully

MATAMATA (1904, 1911)

| | Grains per gallon. |
|------------------------------|--------------------|
| Sodium bicarbonate | 28.10 |
| Total solids | 46.66 |
| Temperature 106° F. | |

HAUPIRI (1901)

| | |
|---------------------------|------|
| Sodium silicate | 7.3 |
| Total solids | 19.3 |

WHANGAPE-WAIKATO (1909)

| | |
|-----------------------------|-------|
| Sodium chloride | 17.25 |
| Total solids | 35.50 |
| Temperature 150° to 200° F. | |

TE TEKŌ (1909)

| | |
|------------------------------|------|
| Sodium bicarbonate | 14.2 |
| Total solids | 26.2 |
| Temperature 150° F. | |

ROADMAN'S BATH, WAI-O-TAPU (1909)

| | |
|---------------------------------|------|
| Sodium chloride | 40.9 |
| Total solids | 69.7 |
| Temperature (at source) 212° F. | |

TAHEKE-ROTOITI (1908)

| | |
|------------------------|------|
| Silica | 15.0 |
| Total solids | 27.5 |
| Temperature 212° F. | |

MARUA (1903)

| | |
|------------------------|------|
| Total solids | 36.5 |
| Temperature 140° F. | |

MT. EGMONT (1883)

| | |
|-----------------------------|-------|
| Calcium carbonate | 6.72 |
| Total solids | 26.23 |

FRANZ JOSEF (1901)

| | |
|--|-------|
| Total solids (principally sodium chloride and carbonate) | 56.21 |
|--|-------|

LAKE SUMNER (Skey)

| | |
|------------------------|-------|
| Total solids | 18.56 |
| Temperature 93° F. | |

MIRANDA, THAMES (J. A. Pond)

| | Grains per gallon. |
|---------------------------|--------------------|
| Sodium chloride | 15.17 |
| Total solids | 31.27 |
| Temperature 134° F. | |

WANGANUI RIVER, WESTLAND (1907)

| | |
|---------------------------|------|
| Sodium sulphate | 12.4 |
| Sodium silicate | 16.9 |
| Total solids | 45.1 |

RAHU, REEFTON (1915)

| | |
|------------------------------|-------|
| Sodium chloride | 15.97 |
| Sodium bicarbonate | 12.72 |
| Total solids | 37.17 |
| Hydrogen sulphide | 1.55 |

MORINSVILLE (1915)

| | |
|--------------------------------|-------|
| Ferrous bicarbonate | 0.08 |
| Total solids | 13.00 |
| Carbonic acid (free) | 94.52 |
| Temperature cold. | |

KATIKATI (1913)

| | |
|---------------------------|-------|
| Sodium silicate | 5.63 |
| Total solids | 15.48 |

PUKETITIRI: NAPIER (1912)

| | |
|----------------------------|-------|
| Sodium carbonate | 9.41 |
| Total solids | 23.46 |

CLASS II. MURIATED WATERS

The principal ingredient of these waters is common salt.

Taken as a whole, they constitute an important and numerous group, and are distinguished by their geographical distribution and by certain chemical peculiarities. Thus the great majority arise near the coast, especially the east coast of the North Island. A great number of the waters, too, contain very considerable quantities of calcium chloride and of sodium iodide, and a few magnesium chloride. Perhaps it would be more rational to class all these waters together

as muriated, but for practical convenience, while the calcium chloride waters have been included as a subclass, the iodide and magnesium waters have been classed separately. There is a good deal of inevitable overlapping, and some waters are made to appear in more than one class, but this is only another way of stating that nature is infinite in variety and refuses to be bound down by the narrow limits of any scheme of classification.

In Europe many muriated waters, especially the stronger waters, are cold, but in New Zealand cold brines are rare; at any rate, I have not personally come across them. Again, no use is made in New Zealand of the concentrated "*mutter-lauges*" so much employed on the Continent.

Baths of a simple nature, principally immersion baths, have been erected at several of the undermentioned springs, notably at Helensville, which is rapidly assuming the dignity of a spa, Morere, Te Puia, and Tarawera.

Action.—Muriated waters are used internally and for baths. In the latter capacity their effect largely depends upon their concentration, and is that of a skin stimulant, plus, of course, the effects of an ordinary bath at the same temperature (see page 249).

Taken internally, sodium chloride waters of moderate strength stimulate the gastric mucous membrane and increase the activity of the secretion: at the same time they facilitate the solution of albuminous and starchy foods. They are diuretic, and an increased amount of salt is passed in the urine, and in some persons they are laxative. As they promote nutrition, they are useful in some cachexias, and in anæmias in which iron is badly tolerated. Their action on uric acid excretion is but slight, but they are used in asthenic gout. On account of their stimulant action on the gastric glands they are indicated in hypo-acidity, but contra-indicated in hyper-acidity: they are also largely used in chronic catarrh of the pharynx, naso-pharynx, stomach, duodenum, and biliary passages.

MURIATED WATERS

(a) Sodic Muriated Waters

EUROPE

WIESBADEN

| | |
|-----------------------------|----------------------------------|
| Sodium chloride | Grains per gallon. 350 to 490 |
| Temperature 100° to 156° F. | |

NEW ZEALAND

HELENSVILLE (1903)

| | |
|---|--------|
| Sodium chloride | 114.46 |
| Sodium iodide | 0.03 |
| Total solids | 134.68 |
| Gases, H ₂ S and CH ₄ | |
| Temperature 115° to 146° F. | |

HOKIANGA (Pond)

| | |
|---------------------------|---------|
| Sodium chloride | 2,797.4 |
| Total solids | 2,937.5 |

HOKIANGA: ROTOKAKAHI (1905)

| | |
|---------------------------|---------|
| Sodium chloride | 1,350.0 |
| Total solids | 1,543.0 |

RAUKAWA, HAWKE'S BAY (1912-13)

| | |
|---------------------------|-------|
| Sodium chloride | 343.8 |
| Total solids | 405.7 |

PAPAITI, WANGANUI (1886)

| | |
|---------------------------|--------|
| Sodium chloride | 313.41 |
| Total solids | 348.54 |

PIPIRIKI (1888)

Spring on left bank of Wanganui

| | |
|---------------------------|--------|
| Sodium chloride | 121.88 |
| Total solids | 130.61 |

Spring on right bank

| | |
|---------------------------|--------|
| Sodium chloride | 231.64 |
| Total solids | 244.03 |

MOKAU, MOTUKARAMA (1888)

| | |
|--|-----------------------------|
| Total solids (chlorides and some iodide) . . . | Grains per gallon. 844·0 |
| (Analysis incomplete) | |

KATIKATI (1904)

| | |
|---------------------------|--------|
| Sodium chloride | 119·54 |
| Total solids | 137·26 |

McLEAN'S, NAPIER (Skey)

| | |
|------------------------|-------|
| Total solids | 444·7 |
|------------------------|-------|

MAHURANGI, AUCKLAND (Skey)

| | |
|------------------------|-------|
| Total solids | 141·0 |
|------------------------|-------|

MERCURY BAY (1908)

| | |
|---------------------------|-------|
| Sodium chloride | 200·8 |
| Total solids | 259·4 |

ROKOKAKAHI, HOKIANGA (1904)

| | |
|---------------------------|-------|
| Sodium chloride | 1,350 |
| Total solids | 1,543 |

(b) *Calcic Sodid Muriated Waters*

Waters of this class are very strongly represented in New Zealand, and the springs, for the most part arising on the east coast, are distributed over a wide area extending from Poverty Bay to as far south as Banks' Peninsula in the South Island.

Strong solutions of calcium chloride are not very well suited for internal administration, and it is probable that these waters will eventually find their principal rôle as baths. The weaker waters, however, such as those of Great Barrier Island, could well be used for drinking, in exactly the same manner as at Kreuznach, whose waters so closely resemble them. The action of the milder calcium chloride waters is largely that of the simple muriated waters, i.e. diuretic and gastric stimulant, but in the waters richer in calcium the stimulation of the gastric glands would probably be replaced by inhibition: there is at present

unfortunately insufficient clinical or experimental evidence at our disposal of the action of these waters to allow of any dogmatic statement. By their hyper-tonicity¹ some of them are distinctly purgative, but, owing to their very varied and complex composition, their action in this respect is equally varied.

It will be noted that many of the waters of this class are shown also under the heading of Iodine Waters, or of Magnesium or of Chalybeate Waters; indeed, it is hard to decide which is the predominating ingredient in many cases.

While their internal use is perhaps limited, they are invaluable as baths, douches, sprays, and inhalations.

As baths they have the skin-stimulating effects already noted under muriated waters, but being, in New Zealand, much stronger than the simple saline waters, they are much more stimulating, and approach in effect the concentrated "*mutterlauges*" of the Continent or the brine of Droitwich.

At present no facilities for sprays and inhalations exist, but baths of simple immersion type exist at Morere and Te Puia (vide p. 128). In the near future, when better facilities for treatment are forthcoming, these places should be beneficial for arthritic cases, for gastric hyper-acidity, for catarrhal conditions of the naso-pharynx, larynx, and bronchi, for many chronic pelvic conditions in the female, for certain very chronic skin diseases, and, when taken internally, for some cases of chronic urticaria and allied blood conditions.

The nearest European prototypes of such a class of water are perhaps Kreuznach on the Continent and Woodhall Spa in England.

| KREUZNACH | | | | | | Grains per gallon. |
|------------------|---|---|---|---|---|--------------------|
| Calcium chloride | . | . | . | . | . | 140.0 |
| Sodium chloride | . | . | . | . | . | 700.0 |

¹ Vide Appendix, p. 276.

NEW ZEALAND

KAWHIA (1903)

(Vide also "Iodine Waters")

| | Grains per gallon. |
|----------------------------|--------------------|
| Calcium chloride | 585.51 |
| Sodium chloride | 424.55 |
| Total solids | 1,040.76 |

MATAROA (1903, 1905)

(Vide also "Iodine Waters")

| | |
|------------------------------|----------|
| Calcium chloride | 128.21 |
| Sodium chloride | 1,625.25 |
| Magnesium chloride | 85.70 |
| Total solids | 1,843.43 |

OKAIN'S BAY (1904)

(Vide also "Chalybeate Waters")

| | |
|-------------------------------|---------|
| Calcium chloride | 468.5 |
| Sodium chloride | 295.5 |
| Magnesium chloride | 264.8 |
| Ferrous bicarbonate | 26.7 |
| Total solids | 1,128.9 |

This is an artificial spring of cold water obtained from a bore sunk into the recent soil of a rapidly silting-up bay, and is remarkable for the unusually large amount of iron in solution.

NGAKAWAU, BULLER (1917)

| | Grains per gallon. |
|-------------------------------|--------------------|
| Calcium chloride | 41.79 |
| Calcium bicarbonate | 14.35 |
| Sodium chloride | 81.06 |
| Sodium sulphate | 10.29 |
| Total solids | 154.21 |

TE KUITI (1913)

(Vide also "Iodine Waters")

| | |
|---|----------|
| Calcium chloride | 634.76 |
| Sodium chloride | 805.63 |
| Lithium chloride ¹ | 3.36 |
| Total solids | 1,454.46 |

¹ Cf. Lithium in Te Aroha waters, p. 120, and in Hanmer waters, p. 96.

TOTORO, MOKAU RIVER (1905)

(Vide also " Iodine Waters ")

| | | Grains per gallon. |
|------------------|-----------|--------------------|
| Calcium chloride | | 681.0 |
| Sodium chloride | | 748.0 |
| Total solids | | 1,496.0 |

MORERE (1903-1905)

(Vide also " Iodine Waters ")

| | | |
|------------------|-----------|----------|
| Calcium chloride | | 544.78 |
| Sodium chloride | | 1,249.67 |
| Total solids | | 1,899.60 |

Temperature 120° F.

TE PUIA (1906)

(Vide also " Iodine Waters ")

| | | |
|------------------|-----------|--------|
| Calcium chloride | | 153.40 |
| Sodium chloride | | 807.75 |
| Total solids | | 978.69 |

Temperature 150° F.

KOPUOWHARA, MAHIA (1885)

(Vide also " Iodine Waters ")

| | | |
|------------------|-----------|----------|
| Calcium chloride | | 177.82 |
| Sodium chloride | | 1,027.66 |
| Total solids | | 1,241.65 |

GREAT BARRIER ISLAND (1904)

| | | |
|------------------|-----------|--------|
| Calcium chloride | | 103.75 |
| Sodium chloride | | 791.50 |
| Total solids | | 985.23 |

Temperature 180° F.

PAHAUA, WELLINGTON (Skey: also 1878)

(Vide also " Iodine Waters ")

| | | |
|------------------|-----------|----------|
| Calcium chloride | | 128.88 |
| Sodium chloride | | 1,303.32 |
| Total solids | | 1,474.09 |

KOTUKU, GREYMOUTH (borehole 1904)

| | | |
|--|-----------|---------|
| Calcium chloride, sulphate, and bicarbonate. | | 458.8 |
| Sodium chloride | | 5,134.0 |
| Total solids | | 5,936.8 |

WALLINGFORD (Skey)

(Vide also " Iodine Waters ")

| | Grains per gallon. |
|------------------------|--------------------|
| Total solids | 826.0 |

MERCURY BAY (1908)

| | |
|-------------------------------|-------|
| Calcium chloride | 21.6 |
| Calcium bicarbonate | 22.5 |
| Sodium chloride | 200.8 |
| Total solids | 259.4 |

TAUMARANUI (1919)

| | |
|----------------------------|---------|
| Calcium chloride | 532.0 |
| Sodium chloride | 945.0 |
| Total solids | 1,505.0 |

CLASS III. IODINE WATERS

Strictly speaking, the iodine waters might all be classed under one of the other headings, and as a rule under that of calcic muriated waters. The possible importance of iodine as a constituent of mineral water is, however, so great, and the examples of such waters in New Zealand so numerous and important, that I have ventured to separate off the iodide waters in a class to themselves.

Small quantities of iodides and bromides are not uncommon in the saline waters of Europe, and in England are found in the Woodhall waters; but, for the most part, the quantities present are in no way comparable with those in the hot saline waters of New Zealand, where, in addition to iodide of sodium, there is a varying amount of free iodine present, in some cases sufficient to colour the water brown and to make itself very evident to the senses by its pungent fumes. It would appear that, on free exposure of the water to the atmosphere, the sodium iodide is decomposed, with the liberation of free nascent iodine. Such exposure is favoured at such places as Morere, where the hot water falling from the springs in cascades is broken into a fine spray and so exposed intimately to oxidation. The only waters stronger in iodide than these are, so far as I am aware,

the Saratoga Springs, New York, and certain springs in Michigan, U.S.A.

Action.—Iodine waters stimulate lymphatic activity and increase absorption, particularly in glandular organs.¹ They are used internally in cases of enlarged glands and of "scrofulous" conditions generally; in cases of syphilis, though here we are on uncertain ground; in goitre, though here again it is obvious that the cases must be selected; and in certain diseases of the skin.

Their use as baths has been already indicated, under the head of calcic muriated waters.

EUROPE

WOODHALL SPA

| | Grains per gallon. |
|------------------------------|--------------------|
| Potassium iodide | 0.52 |
| Potassium bromide | 3.51 |
| Sodium chloride | 1,406.10 |
| Magnesium chloride | 38.39 |
| Calcium chloride | 105.59 |
| Total solids | 1,562.47 |

NEW ZEALAND

MORERE (1903, 1906)

(Vide "Calcic Muriated Waters")

| | |
|-------------------------|----------|
| Sodium iodide | 2.70 |
| Total solids | 1,858.07 |

(Also sufficient free iodine to tinge the water light brown)

TE PUIA (1907)

(Vide also "Calcic Muriated Waters")

| | |
|-------------------------|--------|
| Sodium iodide | 1.41 |
| Total solids | 978.69 |

KAWHIA (1903)

(Vide also "Calcic Muriated Waters")

| | |
|-------------------------|----------|
| Sodium iodide | 0.47 |
| Bromides | trace |
| Total solids | 1,040.76 |

¹ Kisch.

MATAROA (1906)

(Vide also "Calcic Muriated Waters")

| | Grains per gallon. |
|-------------------------|--------------------|
| Sodium iodide | 1.41 |
| Total solids | 1,879.60 |

PAHAUA (1878: also Skey)

| | |
|-----------------------------|----------|
| Magnesium iodide | 0.58 |
| Magnesium bromide | traces |
| Iodine (free) | 1.59 |
| Total solids | 1,424.09 |

KOPUOWHARA, MAHIA (1885)

| | |
|----------------------------|----------|
| Magnesium iodide | 2.98 |
| Total solids | 1,241.65 |

TE KUITI (1913)

| | |
|----------------------------|----------|
| Lithium chloride | 3.36 |
| Sodium iodide | 0.21 |
| Sodium chloride | 805.63 |
| Calcium chloride | 634.76 |
| Sodium borate | 8.05 |
| Total solids | 1,454.46 |

WEBB'S SPRING, MANGARUHU (1914)

| | |
|--|-----------------|
| Iodides | (not estimated) |
| Total solids, mainly sodium chloride | 1,603.0 |

IHURAU, MASTERTON (1910-11)

| | |
|---------------------------|--------|
| Sodium iodide | 1.68 |
| Sodium chloride | 691.51 |
| Total solids | 762.51 |

WEBER SPRINGS¹ (1913)

| | |
|--|-------|
| Iodine | 4.5 |
| Total solids, mainly chlorides | 650.0 |

MARANGA, NAPIER (1910-11)

(Incomplete analysis)

| | |
|--|-------------|
| Sodium iodide (in different springs) | 1.96 to 2.8 |
| Chlorides | 1,036.7 |

¹ Very small yield.

CLASS IV. ALKALINE WATERS

(a) Simple Alkaline Waters

The principal ingredients of these waters is sodium bicarbonate, and any sodium chloride present—and some always is—is only in trifling amount. There is also generally present a fair amount of carbonic acid gas.

Such waters are not common in New Zealand, being almost confined to the Thames Valley, at Puriri and Te Aroha. Of these two examples, Puriri may fairly be said to merit the title of “simple alkaline,” while the Te Aroha waters might with equal truth be classed as “muriated alkaline,” and constitute an intermediate link between the two classes.

Taken internally they act as antacids, and in large doses inhibit the gastric and pancreatic secretion, being thus indicated in gastric hyper-acidity. In small doses they are said to stimulate the gastric mucous membrane, more especially if there is reasonable motor activity of the stomach, and they are largely used in hypo-acidity.

They have also a diuretic action, and as they have a solvent action on mucus, they are useful in bronchial catarrh to facilitate expectoration.

In gout they are very freely used, and in gouty glycosuria, but as they have a “lowering” effect they are more suited for robust than for debilitated subjects.

The carbonic acid which they contain tends to increase both the secretory and motor activity of the stomach. They are often associated, as at Te Aroha, with mild chalybeate waters, and their use aids the action of iron in anæmia.

There is always some sodium chloride present in these waters, so that as a subclass they pass insensibly into the muriated alkaline waters, and the nearer they approach to that category the less “lowering” they are.

EUROPE

VICHY

| | | |
|------------------------------|-------------------------|--------------------|
| | | Grains per gallon. |
| Sodium bicarbonate | 336 to 350 | |
| Free carbonic acid | 120 cub. in. per gallon | |
| Temperature 89° to 108.5° F. | | |

NEW ZEALAND

PURIRI

| | |
|--------------------------------|--------------------|
| | Grains per gallon. |
| Sodium bicarbonate | 452.39 |
| Total solids | 537.11 |
| Free carbonic acid "abundant." | |
| Temperature 60° F. | |

TE AROHA (1903-4-5)

| | |
|------------------------------|-------|
| Sodium bicarbonate | 657.4 |
| Sodium chloride | 59.5 |
| Total solids | 784.3 |
| Temperature 135° F. | |

TAPAPA, MATAMATA (1911)

| | |
|------------------------------|-------|
| Sodium bicarbonate | 31.29 |
| Sodium silicate | 7.0 |
| Total solids | 48.16 |

OTWAY'S SPRING, WAITOA (1913)

| | |
|--------------------------------|-------|
| Sodium bicarbonate | 42.63 |
| Sodium silicate | 14.42 |
| Ferrous bicarbonate | 0.35 |
| Total solids | 73.57 |
| Carbonic acid (free) | 19.88 |

MOTU (1917)

| | |
|------------------------------|-------|
| Sodium bicarbonate | 32.41 |
| Total solids | 39.13 |

(b) *Muriated Alkaline Waters*

In these waters considerable quantities of sodium chloride are present with the bicarbonate, and, while they are useful, roughly, in the same class of cases as the last, the sodium chloride exerts its stimulating effect on the digestive organs, and they are generally regarded as less "lowering" than the more purely alkaline waters.

EUROPE

ROYAT

| | | | | | | Grains per gallon. |
|---------------------|---|---|---|---|---|--------------------|
| Sodium chloride | . | . | . | . | . | 119.0 |
| Sodium bicarbonate | . | . | . | . | . | 91.0 |
| Calcium bicarbonate | . | . | . | . | . | 133.0 |
| Ferrous bicarbonate | . | . | . | . | . | 2.8 |
| Lithium chloride | . | . | . | . | . | 2.4 |
| Total solids | . | . | . | . | . | 392.0 |

NEW ZEALAND

WAIWERA (Skey: also 1904)¹

| | | | | | | |
|--------------------|---|---|---|---|---|-------|
| Sodium chloride | . | . | . | . | . | 116.7 |
| Sodium bicarbonate | . | . | . | . | . | 87.5 |
| Total solids | . | . | . | . | . | 219.5 |

Temperature 105° F.

OHAEWAI (1904)

(Cf. "Mercurial Mud")

| | | | | | | |
|--------------------|---|---|---|---|---|--------|
| Sodium chloride | . | . | . | . | . | 65.10 |
| Sodium bicarbonate | . | . | . | . | . | 134.50 |
| Total solids | . | . | . | . | . | 255.66 |

Temperature 180° F.

This water is strongly sulphuretted, and might with equal justice be placed among the sulphur waters, some of the springs here containing as much as 108 grains per gallon of sulphuric acid. For further analyses of the Ohaewai Springs vide p. 210.

CLASS V. MAGNESIUM WATERS

These waters are generally classed with the sulphated or with the earthy or calcarous waters, and indeed their magnesium content is generally overshadowed by other ingredients. It is, however, a matter of practical convenience to place them together in one class, as this facilitates reference and is of some practical importance, as the term "magnesia spring" is so widespread and popular in application.

The usual salts met with are the carbonate, the chloride,

¹ The 1904 analysis appears to have been made from a minor spring, and shows an indifferent or simple thermal water containing sodium chloride and bicarbonate, but total solids only 16 grains per gallon.

and the sulphate, and we can therefore arrange the magnesium waters in three groups.

(a) *Magnesium Carbonate Waters*

These waters, in which the magnesium salt is generally in company with calcium bicarbonate, are diuretic and antacid, and, in the absence of much calcium salt, laxative.

In the calcareous-water spas, such as Contrexéville and Wildungen, the waters are taken for their calcium rather than their magnesium content, and indeed, it is hard to find a water exactly analogous to the alkaline magnesia waters of New Zealand such as Te Aroha. These latter are indicated in dyspepsia and in gout associated with dyspeptic troubles.

NEW ZEALAND

PAEROA (1904)

| | Grains per gallon. |
|---------------------------------|--------------------|
| Calcium bicarbonate | 35.5 |
| Magnesium bicarbonate | 73.0 |
| Sodium bicarbonate | 39.4 |
| Total solids | 167.8 |
| Free CO ₂ | 26.0 |

TE AROHA

Springs Nos. 20, 21, and 22, vide p. 118 for analyses.

See also "Te Aroha Cold Springs," p. 120.

WAIRONGOA

(Vide also "Calcareous Waters")

| | Grains per gallon |
|---------------------------------|-------------------|
| Calcium bicarbonate | 67.86 |
| Magnesium bicarbonate | 35.89 |
| Total solids | 165.75 |

KAMO

(Vide also "Calcareous Waters")

| | |
|---------------------------------|--------|
| Calcium bicarbonate | 57.68 |
| Magnesium bicarbonate | 17.05 |
| Sodium bicarbonate | 38.64 |
| Total solids | 164.36 |

MATAMATA (1912)

| | Grains per gallon. |
|--|--------------------|
| Calcium bicarbonate | 6.09 |
| Sodium bicarbonate | 31.29 |
| Magnesium bicarbonate and chloride | 3.43 |
| Total solids | 48.16 |

MATAMATA (1913)

| | |
|---------------------------------|-------|
| Calcium bicarbonate | 18.82 |
| Sodium bicarbonate | 14.77 |
| Magnesium bicarbonate | 10.99 |
| Total solids | 58.03 |

RAUKAWA (1913)

| | |
|---------------------------------|-------|
| Calcium bicarbonate | 17.6 |
| Magnesium bicarbonate | 24.3 |
| Sodium bicarbonate | 16.0 |
| Sodium chloride | 343.8 |
| Total solids | 405.7 |

ORMOND VALLEY, vide p. 185.

IHURAU, MASTERTON, vide "Iodine Waters."

PARAKAO, vide p. 186.

(b) Magnesium Chloride Waters

In these waters the magnesium chloride is generally associated with the sulphate and with large quantities of common salt. It is a class including some of the more potent purgative waters in Europe, such as Friedrichshall and Franz Josef. In New Zealand these waters are practically confined to the neighbourhood of Banks' Peninsula and Lyttelton Harbour, and the waters all contain a fair amount of calcium chloride, which somewhat detracts from their usefulness. They are all laxative and diuretic. In the strongest of these waters, Okain's Bay, the amount of calcium and other salts is so large as to make the water unsuitable for a purgative, though its purgative action is nevertheless strong.

EUROPE

FRIEDRICHSHALL

| | Grains per gallon. |
|------------------------------|--------------------|
| Sodium chloride | 1,680 |
| Sodium sulphate | 1,260 |
| Magnesium chloride | 840 |

NEW ZEALAND

OKAIN'S BAY (1904)

| | Grains per gallon. | | | | | |
|-------------------------------|--------------------|---|---|---|---|---------|
| Sodium chloride | . | . | . | . | . | 295.5 |
| Potassium chloride | . | . | . | . | . | 2.4 |
| Calcium chloride | . | . | . | . | . | 468.5 |
| Magnesium chloride | . | . | . | . | . | 264.8 |
| Magnesium sulphate | . | . | . | . | . | 69.0 |
| Ferrous bicarbonate | . | . | . | . | . | 26.7 |
| Silica | . | . | . | . | . | 2.0 |
| Total solids | . | . | . | . | . | 1,128.9 |

(Results expressed in grains per gallon)

| — | Charteris Bay, Lyttelton (1909). | Church Bay, Lyttelton (1909). | Heathcote Valley (1909). | Heathcote Valley (1914). |
|--------------------------------|--|-------------------------------------|--------------------------------|--------------------------------|
| Potassium chloride | 6.5 | 3.35 | 3.65 | 54.67 |
| Sodium chloride | 40.4 | 33.20 | 51.40 | — |
| Magnesium chloride | 35.3 | 38.80 | 8.50 | 3.99 |
| Magnesium sulphate | 12.4 | 4.95 | 10.35 | 9.24 |
| Sodium bicarbonate | 2.9 | 7.90 | 4.80 | — |
| Calcium bicarbonate | 62.0 | 20.20 | 27.50 | — |
| Ferrous bicarbonate | 1.0 | 2.40 | 1.50 | — |
| Sodium silicate | 4.1 | 5.40 | 5.00 | — |
| Carbonic acid (free) | — | — | — | 14.77 |
| Total solids | 164.6 | 116.20 | 112.70 | 82.67 |

AMBERLEY (1913)

| | Grains per gallon. | |
|------------------------------|--------------------|--------|
| | No. 1. | No. 2. |
| Magnesium chloride | 5.67 | — |
| Magnesium sulphate | 0.35 | 3.36 |
| Total solids | 45.31 | 75.58 |

(c) Magnesium Sulphate Waters

With the exception of the above, and especially of the somewhat anomalous Okain's Bay water, there have so far been found few sulphated waters in New Zealand.

WAIKOHU (1909-10)

| | Grains per gallon. | | | | | |
|--------------------------------|--------------------|---|---|---|---|-------|
| Sodium sulphate | . | . | . | . | . | 53.0 |
| Aluminium sulphate | . | . | . | . | . | 93.0 |
| Iron sulphate | . | . | . | . | . | 1.5 |
| Calcium sulphate | . | . | . | . | . | 34.0 |
| Magnesium sulphate | . | . | . | . | . | 13.5 |
| Total solids | . | . | . | . | . | 210.5 |
| Free CO ₂ | . | . | . | . | . | 3.5 |

CLASS VI. THE CALCAREOUS OR EARTHY WATERS

These waters contain calcium sulphate or carbonate or both.

New Zealand is somewhat poor in springs of this class, calcium, when present in any quantity, being generally in the form of the chloride, and waters of this type generally fall under the heading of muriated waters or of magnesium waters.

Action.—Internally they act as astringents and antacids, and are used in digestive disturbances ; they are also diuretic, and it is in this direction that their principal sphere of usefulness lies in the treatment of uric acid gravel, gouty oxaluria, and cystitis.

Incidentally they contain as a rule free carbonic acid, and in some of the waters, for instance Kamo, the gas is so abundant that its importance from a therapeutic point of view completely overshadows that of the saline constituents, more especially when the water is used for baths.

Thus the baths at Kamo can be used in the same way as those at Nauheim, either in heart cases or as a tonic measure in other conditions, and though at present they are little developed, there can be no doubt whatever that in the near future their importance will be fully recognized. The carbonic acid has also a considerable commercial significance.

Many of these waters, too, contain appreciable quantities of iron in an easily assimilable form, so that they may also be found classed under the chalybeates, and are indicated in chlorosis and in other cases of anæmic debility.

EUROPE

CONTREXÉVILLE

| | Grains per gallon. |
|---------------------------------|--------------------|
| Calcium bicarbonate | 28.0 |
| Calcium sulphate | 105.0 |
| Magnesium bicarbonate | 2.1 |

Temperature cold

NEW ZEALAND

WAIKOURA, KAEŌ (1909)

| | Grains per gallon. |
|-------------------------------|--------------------|
| Calcium bicarbonate | 127.5 |
| Sodium bicarbonate | 126.6 |
| Total solids | 304.1 |

WAIKONGA

(Vide also "Table Waters" and "Magnesium Waters")

| | |
|---------------------------------|--------|
| Calcium bicarbonate | 67.86 |
| Magnesium bicarbonate | 35.89 |
| Total solids | 165.75 |

KAMO

(Vide also "Table Waters," "Magnesium Waters," and
"Chalybeate Waters")

| | |
|---------------------------------|--------|
| Calcium bicarbonate | 57.68 |
| Sodium bicarbonate | 38.64 |
| Magnesium bicarbonate | 17.05 |
| Total solids | 164.36 |

Temperature 78° F.

COPLAND RIVER, WESTLAND (1907)

| | |
|-------------------------------|-------|
| Calcium bicarbonate | 27.0 |
| Sodium bicarbonate | 76.6 |
| Total solids | 142.3 |

FOX RIVER, WESTLAND (1907)

| | |
|-------------------------------|------|
| Calcium bicarbonate | 10.5 |
| Sodium bicarbonate | 44.4 |
| Total solids | 79.5 |

TE AROHA (Cold Springs) (1913)

| | |
|---------------------------------|-------|
| Calcium bicarbonate | 48.16 |
| Magnesium bicarbonate | 15.4 |
| Total solids | 78.89 |

ORMOND VALLEY (1912)

| | |
|---------------------------------|-------|
| Calcium bicarbonate | 16.17 |
| Sodium bicarbonate | 8.54 |
| Magnesium bicarbonate | 6.86 |
| Total solids | 35.77 |

IHURAU, MASTERTON (1910)

(Vide also "Iodine Waters")

| | Grains per gallon. |
|---------------------------------|--------------------|
| Calcium bicarbonate | 42.7 |
| Magnesium bicarbonate | 12.25 |
| Magnesium chloride | 7.14 |
| Total solids | 762.51 |

PARAKAO, WHANGAREI (1911)

| | | |
|-----------------------------------|----------------|-------|
| Calcium and magnesium bicarbonate | } Total solids | 735.0 |
| Sodium chloride and carbonate | | |

CLASS VII. CHALYBEATE WATERS

Therapeutically, the most important of these waters are those containing the bicarbonate of iron and free carbonic acid gas.

Many of the chalybeate springs of New Zealand contain large, and sometimes enormous, quantities of the sulphate, and, while these are noted here, they are, except as baths, of little practical use in so far as the iron salt is concerned.

The ferrous bicarbonate, on the other hand, though generally present in but small amount, is easily assimilated, especially, as is usually the case, when associated with abundant carbonic acid gas; while it is to the presence of this gas that baths of such waters owe their stimulating properties. On the escape of this gas the iron salt is apt to be precipitated as the oxide, and such waters must be carbonated if bottled.

Pharmacological Action. — Chalybeate waters are indicated in the anæmia consequent on previous illness or on hæmorrhage, or in simple chlorosis. In the latter case more especially they should be combined with purgatives. Owing probably to their association with carbonic acid and with other salts they are generally diuretic, and increase the excretion of urea and proteid catabolism generally. During a course of these waters a diet of easily digested foods, rich in proteids and carbohydrates, but poor in fats, is generally recommended.¹

¹ Weber: *Balneo-therapy*.

The waters are contra-indicated in plethoric conditions and in cases in which the digestive apparatus is much deranged.

EUROPE

SPA

Grains per gallon.

| | |
|-------------------------------|------|
| Ferrous bicarbonate | 6.44 |
| Carbonic acid " abundant " | |

Temperature cold

NEW ZEALAND

TE AROHA (Cold Springs, 1913)

(Vide also Spring No. 20, p. 118)

| | |
|--------------------------------|-------|
| Ferrous bicarbonate | 4.55 |
| Total solids | 33.25 |
| Carbonic acid (free) | 76.93 |

TAUPIRI¹ (1913)

| | |
|--------------------------------|-------|
| Ferrous bicarbonate | 11.08 |
| Total solids | 69.14 |
| Carbonic acid (free) | 13.02 |

WAITANGI, ROTOEHU (1903-1904)

| | |
|-----------------------------------|-------|
| Ferrous bicarbonate | 0.5 |
| Total solids | 58.73 |
| Carbonic acid, free effervescence | |

Temperature 120° F.

KAMO

(Vide also " Calcareous Waters ")

| | |
|--|------|
| Ferrous bicarbonate (estimated as oxide) | 0.28 |
|--|------|

RAHU, REEFTON (1915)

| | |
|-------------------------------|-------|
| Ferrous bicarbonate | 0.14 |
| Sodium bicarbonate | 12.62 |
| Sodium chloride | 15.97 |
| Total solids | 37.17 |

WAIKOURA, KAE0 (1909)

(Vide also " Calcareous Waters ")

| | |
|-------------------------------|-------|
| Ferrous bicarbonate | 2.9 |
| Total solids | 304.1 |

SODA SPRING, NGAWHA (1909)

| | |
|--------------------------------|------|
| Ferrous bicarbonate | 1.2 |
| Carbonic acid (free) | 35.0 |
| Total solids | 31.8 |

¹ From a bore: this water is not used therapeutically.

KOTUKU, GREYMOUTH (1904)

| | Grains per gallon. |
|-------------------------------|--------------------|
| Ferrous bicarbonate | 4.10 |
| Total solids | 201.25 |

OKAIN'S BAY (1904)

(Vide also "Muriated Waters" and "Magnesium Waters")

| | |
|-------------------------------|---------|
| Ferrous bicarbonate | 26.7 |
| Total solids | 1,128.9 |

PATANGATA (1902)

| | |
|-------------------------------|-------|
| Ferrous bicarbonate | 0.6 |
| Total solids | 176.4 |

AORANGI (Skey)

| | |
|-------------------------------|-------|
| Ferrous bicarbonate | 0.94 |
| Total solids | 13.75 |

PAEROA (1905)

(Vide also "Magnesium Waters")

| | |
|-------------------------------|-------|
| Ferrous bicarbonate | 1.6 |
| Total solids | 167.8 |
| Free carbonic acid | 26.0 |

Temperature 80° F.

WAIWERA

(Vide also "Muriated Alkaline Waters")

| | |
|-------------------------------|--------|
| Ferrous bicarbonate | 0.68 |
| Total solids | 219.55 |

MAUNGAPAKEHA, TAUPO (1907)

(Vide also "Iodine Waters")

| | |
|-------------------------------|--------|
| Ferrous bicarbonate | 4.00 |
| Total solids | 374.00 |

IRON SPRING, TERRACES, TAUPO (1906)

| | |
|-------------------------------|-------|
| Ferrous bicarbonate | 0.28 |
| Total solids | 63.04 |
| Carbonic acid | 16.90 |

Temperature 120° F.

SODA WATER SPRING, TERRACES, TAUPO (1906)

| | |
|-------------------------------|-------|
| Ferrous bicarbonate | 0.84 |
| Total solids | 64.19 |
| Carbonic acid | 47.70 |

Temperature cold

ARSENIC SPRING ¹, THE SPA, TAUPŌ (1906)

| | Grains per gallon. |
|-------------------------------|--------------------|
| Ferrous bicarbonate | 0·56 |
| Total solids | 55·52 |

DEVIL'S EYEGGLASS, WAIRAKEI ² (1906)

| | |
|-------------------------------|--------|
| Ferrous bicarbonate | 1·20 |
| Total solids | 117·25 |

THE BOILERS, WAIRAKEI ² (1906)

| | |
|-------------------------------|--------|
| Ferrous bicarbonate | 1·12 |
| Total solids | 100·77 |

WAI-O-TAPU

Chalybeate waters exist here, but so far no potable specimens have been analysed.

IHURAU, MASTERTON (1910-11)

(Vide also " Iodine Waters ")

| | Grains per gallon. |
|-------------------------------|--------------------|
| Ferrous bicarbonate | 1·19 |
| Total solids | 761·51 |

WAIKOHU (1909-10)

(Vide also " Sulphated Waters ")

| | |
|-------------------------|-------|
| Iron sulphate | 1·5 |
| Total solids | 210·5 |

IODINE SPRING, ³ ROTOMAHANA (1904)

| | |
|-------------------------------|--------|
| Ferrous bicarbonate | 0·62 |
| Total solids | 157·79 |

Temperature 212° F.

ROTORUA WATERS

The majority of these waters contain iron, but as this is not an important or essential feature two examples only are given as types of the rest.

RACHEL SPRING, ROTORUA (1913)

| | Grains per gallon. |
|-------------------------------|--------------------|
| Ferrous bicarbonate | 0·01 |
| Total solids | 118·84 |

¹ This spring contains no arsenic.

² These waters are not potable.

³ Contains no iodine.

190 THE HOT SPRINGS OF NEW ZEALAND

POSTMASTER SPRING, ROTORUA (1907)

| | | | | | | | Grains per gallon. |
|------------------|---|---|---|---|---|---|--------------------|
| Ferrous sulphate | . | . | . | . | . | . | 0.52 |
| Total solids | . | . | . | . | . | . | 86.81 |

OHAEWAI, SPRING NO. 1 (1909)

| | | | | | | | |
|------------------|---|---|---|---|---|---|------|
| Ferrous sulphate | . | . | . | . | . | . | 4.1 |
| Total solids | . | . | . | . | . | . | 45.6 |

MOTU, GISBORNE (1904)

| | | | | | | | |
|------------------|---|---|---|---|---|---|--------|
| Ferrous sulphate | . | . | . | . | . | . | 44.68 |
| Total solids | . | . | . | . | . | . | 379.31 |

WHITE ISLAND

(Skey : vide also " Acid Waters ")

| | | | | | | | |
|------------------|---|---|---|---|---|---|-----------|
| Ferrous sulphate | . | . | . | . | . | . | 1,059.00 |
| Total solids | . | . | . | . | . | . | 13,638.00 |

Temperature 212° F.

WHALE ISLAND (Pond)

| | | | | | | | |
|------------------|---|---|---|---|---|---|--------|
| Ferrous sulphate | . | . | . | . | . | . | 9.38 |
| Total solids | . | . | . | . | . | . | 250.30 |

Temperature 198° F.

AKITIO, WELLINGTON (Skey)

| | | | | | | | |
|------------------|---|---|---|---|---|---|-------|
| Iron and alumina | . | . | . | . | . | . | 0.93 |
| Total solids | . | . | . | . | . | . | 37.65 |

ABBOTSFORD, OTAGO (1882)

(Analysis incomplete)

| | | | | | | | |
|---------------------|---|---|---|---|---|---|--------|
| Ferrous bicarbonate | | | | | | | |
| Total solids | . | . | . | . | . | . | 304.00 |

BAY OF ISLANDS (Skey)

| | | | | | | | |
|--------------|---|---|---|---|---|---|--------|
| Iron oxide | . | . | . | . | . | . | 2.23 |
| Total solids | . | . | . | . | . | . | 134.62 |

WAIKOHU (1910)

| | | | | | | | |
|------------------|---|---|---|---|---|---|--------|
| Ferrous sulphate | . | . | . | . | . | . | 1.50 |
| Total solids | . | . | . | . | . | . | 210.50 |

NEILSON'S SPRING, NGAWHIA (1909)

| | | | | | | | |
|----------------------|---|---|---|---|---|---|------|
| Ferrous bicarbonate | . | . | . | . | . | . | 1.2 |
| Total solids | . | . | . | . | . | . | 31.8 |
| Carbonic acid (free) | . | . | . | . | . | . | 35.0 |

| COPLAND RIVER (1906) | | | | | | Grains per gallon. |
|----------------------|---|---|---|---|---|--------------------|
| Ferrous bicarbonate | . | . | . | . | . | 2.0 |
| Total solids | . | . | . | . | . | 142.3 |

| FOX RIVER (1906) | | | | | | |
|---------------------|---|---|---|---|---|------|
| Ferrous bicarbonate | . | . | . | . | . | 1.0 |
| Total solids | . | . | . | . | . | 79.5 |

The following springs contain appreciable quantities of iron, but the quantitative analysis is incomplete :

ONETAPU, AMBERLEY.

CLASS VIII. SULPHUR (SILICEOUS) WATERS

The sulphur waters constitute by far the largest and most important group of mineral waters in New Zealand. This is as might be expected in a highly volcanic country whose activity has not yet by any means entirely died down. They are characterized by their very high temperature and by their large siliceous content. The group, though so well defined physically by the characteristic odour of the sulphides, is by no means so well defined when it comes to classification of individual waters. For many waters that otherwise would indubitably be classed as saline or chalybeate, as witness the astounding White Island water (p. 198), are yet highly sulphurous, and could hardly be omitted from a list of sulphur waters.

In England the sulphur waters are cold, and often highly mineralized, and are more important for internal than for external use ; on the Continent of Europe there are very numerous hot sulphur springs in some respects comparable to the New Zealand waters, but lacking their large amount of silica. The waters of some of the most famous spas are of this nature, and in such spas bathing, as in New Zealand, has been brought to a high pitch of refinement and efficiency, while the internal administration of the water is often comparatively a secondary matter.

To obtain, however, waters at all strictly comparable

we have to go to the United States or to Japan, where some of the waters are almost identical.

To illustrate these points analyses are given of an English cold sulphur spring, of a Continental hot spring, and of an American siliceous one.

As a full account of the pharmacological and physical action of sulphur waters is given in the chapter on Rotorua (p. 67 et seq.), it is unnecessary to discuss the matter further here.

The sulphur waters may be divided into two main classes—the alkaline or neutral, and the acid.¹ The latter class is practically unrepresented in Europe except by such weakly acidified springs as those of Levico.

Subclass (a), The Alkaline Sulphur Waters

For the most part the specific gravity of these waters is not high, the largest ingredients being the chloride and silicate of sodium, and the alkalinity is moderate. For all practical purposes their most marked characteristic is the amount of silicate they contain, and it is this ingredient which gives to the alkaline waters of the Rotorua district their peculiarly bland and satiny feel and makes them so valuable for bath purposes. A similar condition causes the “unctuous” sensation of the “*sources savonneuses*” at Plombières.

Some of the alkaline waters contain appreciable quantities of borates and are, for convenience, classified under the head of borated waters.

As the highly siliceous waters shade off imperceptibly into the less siliceous, it has not seemed convenient to make them a separate class, and they are therefore all included here under the term “sulphur waters.” For a fuller discussion on the action of the alkaline silicates the reader is referred to page 67.

¹ The term “acidulated waters” applied to waters containing carbonic acid gas must be clearly distinguished. The acids here referred to are sulphuric acid or hydrochloric acid.

ENGLAND

OLD SULPHUR WELL, HARROGATE

*
Grains per gallon.

| | | | | | | | |
|-----------------------|---|---|---|---|---|---------------------------|----------|
| Sodium sulphide | . | . | . | . | . | . | 5.21 |
| Sodium chloride | . | . | . | . | . | . | 893.67 |
| Magnesium chloride | . | . | . | . | . | . | 48.28 |
| Calcium chloride | . | . | . | . | . | . | 43.63 |
| Barium chloride | . | . | . | . | . | . | 6.56 |
| Total solids | . | . | . | . | . | . | 1,047.56 |
| Sulphuretted hydrogen | . | . | . | . | . | 10.46 cub. in. per gallon | |
| Carbonic acid | . | . | . | . | . | 40.10 cub. in. per gallon | |

Temperature cold

FRANCE

BAGNÈRES-DE-LUCHON

Grains per gallon.

| | | | | | | | |
|-----------------|---|---|---|---|---|---|------------|
| Sodium sulphide | . | . | . | . | . | . | 3.9 to 4.9 |
| Sodium chloride | . | . | . | . | . | . | 14.0 |

Temperature 61° F. to 152° F.

NEW ZEALAND

RACHEL SPRING, ROTORUA (1913)

| | | | | | | | |
|--------------------|---|---|---|---|---|---|--------|
| Sodium sulphide | . | . | . | . | . | . | 10.27 |
| Sodium chloride | . | . | . | . | . | . | 65.87 |
| Sodium silicate | . | . | . | . | . | . | 23.78 |
| Sodium bicarbonate | . | . | . | . | . | . | 13.47 |
| Carbonic acid | . | . | . | . | . | . | 9.17 |
| Total solids | . | . | . | . | . | . | 118.84 |

Temperature 194° F.

Under this heading come, with the exception of certain muddy geysers of the type of Waimangu, practically the whole of the springs of the Thermal District which exhibit or tend to exhibit geyser action. Thus would be included many springs at Tokaanu, the Taupo geysers, the springs of the geyser valley at Wairakei, numberless springs at Wai-o-tapu and Orakei-Korako, and the Whakarewarewa and Ohinemutu geysers. The analysis of a few of these is given as a type of the rest.

Many of these waters contain very little salts, and a few so little sulphide that they might with equal justice be classed under the heading of "Simple Thermal Waters," but for convenience they are placed all together here, as they are all of the siliceous sulphur type.

OIL BATH, ROTORUA (Skey)¹

| | Grains per gallon. |
|--------------------------------|--------------------|
| Silica and silicates | 29.00 |
| Sodium chloride | 66.34 |
| Total solids | 104.54 |
| Temperature at source 212° F. | |

(This water owes its soft, almost oily, feel to the large amount of silicates in solution.)

SPOUT BATH, ROTORUA (Skey)

| | Grains per gallon. |
|-------------------------------|--------------------|
| Sodium silicate | 16.32 |
| Sodium chloride. | 53.61 |
| Total solids | 87.78 |
| Temperature at source 212° F. | |

KUIRAU, ROTORUA (Skey)

| | |
|---------------------------|-------|
| Silicates | 22.00 |
| Sodium chloride | 45.70 |
| Total solids | 79.85 |

Temperature varies in different springs, 140° F.

(This is a hot lake fed by numerous springs.)

TE KOUTU, ROTORUA (Skey)

| | |
|---------------------------|-------|
| Sodium silicate | 32.12 |
| Total solids | 72.78 |

(This spring has recently dried up, its course being diverted.)

WAIHUNUHUNUKURI (Lake House Hotel), ROTORUA (Hector)

| | |
|------------------------|-------|
| Total solids | 58.40 |
|------------------------|-------|

WAIKITE, OHINEMUTU, ROTORUA (1904)

| | |
|------------------------------|-------|
| Sodium chloride | 38.75 |
| Sodium bicarbonate | 20.03 |
| Silicates | 24.36 |
| Total solids | 90.28 |

¹ These springs are all boiling: many of them are actual geysers. Their true temperature, owing to the elevation of the thermal plateau, is less than 212° F., but the corrected boiling-point is used for convenience.

In the case of the geysers this temperature increases directly as the distance below the surface at which it is taken.

MATUATONGA, ROTORUA (Hector)

| | Grains per gallon. |
|---------------------------|--------------------|
| Sodium chloride | 66.44 |
| Sodium silicate | 29.27 |
| Total solids | 113.27 |

HANMER (1913)

(Vide also " Borated Waters ")

| | |
|---------------------------|-------|
| Sodium chloride | 52.75 |
| Sodium borate | 17.57 |
| Sodium sulphide | 1.45 |
| Total solids | 81.68 |

Temperature 120 F.

CROW'S NEST GEYSER, TAUPO (Hector)

| | |
|------------------------|-------|
| Total solids | 153.6 |
|------------------------|-------|

Temperature 212° F.

WITCH'S CAULDRON, TAUPO (Hector)

| | |
|------------------------|-------|
| Total solids | 166.4 |
|------------------------|-------|

Temperature 212° F.

WAIARIKI, TAUPO (Hector)

| | |
|------------------------|------|
| Total solids | 86.4 |
|------------------------|------|

TOP SPRING, TERRACES, TAUPO (1906)

| | |
|---------------------------|--------|
| Sodium chloride | 43.66 |
| Total solids | 105.80 |

Temperature 184° F.

SOUTH BAY SPRING, TERRACES, TAUPO (1906)

| | |
|---------------------------|--------|
| Sodium chloride | 56.10 |
| Total solids | 107.72 |

Temperature 180° F.

A. C. BATH, TAUPO (1906)

| | |
|------------------------|-------|
| Total solids | 46.43 |
|------------------------|-------|

Temperature 102° F.

OLD SULPHUR SPRING, TAUPO (1906)

| | |
|------------------------|-------|
| Total solids | 63.79 |
|------------------------|-------|

Temperature 135° F.

CHAMPAGNE POOL, WAIRAKEI (1906)

| | Grains per gallon. |
|---------------------------|--------------------|
| Sodium chloride | 195.20 |
| Total solids | 242.68 |

Temperature 212° F.

RED CORAL GEYSER, WAIRAKEI (1906)

| | |
|---------------------------|--------|
| Sodium chloride | 39.35 |
| Total solids | 100.77 |

CHAMPAGNE POOL, WAI-O-TAPU (1909)

| | |
|--------------------------------|-------|
| Sodium chloride | 220.4 |
| Total solids | 288.2 |
| Carbonic acid (free) | 13.2 |

Temperature 212° F.

ROTOITIPAKU, ONEPU (1904)

| | |
|---------------------------|--------|
| Sodium chloride | 50.75 |
| Sodium sulphate | 10.08 |
| Sodium silicate | 22.20 |
| Total solids | 100.68 |

UMUPOKAPOKA, ONEPU (1904)

| | |
|---------------------------|--------|
| Sodium chloride | 66.76 |
| Sodium sulphate | 5.40 |
| Sodium silicate | 22.68 |
| Total solids | 108.70 |

Temperature 180° F.

MANUPIRUA, ROTOITI (1904)

| | |
|--------------------------------|-------|
| Sodium chloride | 13.52 |
| Sodium silicate | 14.49 |
| Total solids | 44.91 |
| Carbonic acid (free) | 13.72 |

Temperature 105° F.

IODINE SPRING,¹ TARAWERA, ROTOMAHANA

| | |
|---------------------------|--------|
| Sodium chloride | 93.60 |
| Sodium silicate | 32.69 |
| Total solids | 157.79 |

Temperature 212° F.

TAUPO, TERRACES (1907)

| | |
|------------------------------|--------|
| Sodium chloride | 49.96 |
| Sodium bicarbonate | 14.80 |
| Sodium silicate | 25.90 |
| Total solids | 117.17 |

¹ Contains no iodine.

Subclass (b), Acid Sulphur Waters

With the exception that they are much more siliceous, the alkaline sulphur waters bear a fairly close resemblance to numerous sulphur waters in Europe, but for a type of the acid sulphur waters we have to look to America, there being no waters of this nature used at the European spas. The nearest European approach to the acid springs of New Zealand is to be found in the waters of Levico (Austria), which contain a small amount of free sulphuric acid, and in the peat baths of Austria, which contain free sulphuric and formic acids and sulphate of iron.

Strong sulphuric acid waters are found in the United States, where, contrary to the New Zealand experience, some of the geysers are acid. Such waters are found in the Yellowstone, in the California geysers, in some of the Virginian springs, and in the Oak Orchard Spring, New York, and, above all, in Iowa, where there is a spring with 409 grains of free sulphuric acid to the U.S. gallon.

These waters are used as baths only, and *it is on these baths more than on any other thing that the great reputation of the New Zealand spas is built.*

Their physiological and therapeutical action is fully discussed under the head of Rotorua (p. 79).

ROTORUA ACID WATERS

(Analyses in grains per gallon)

| — | Postmaster Spring (1907). | Old Priest Spring (1907). | New Priest Spring (1907). | Sulphur Point Effervescing Spring (1907). |
|-----------------------|---------------------------------|---------------------------------|---------------------------------|--|
| Sulphuric acid (free) | 22.29 | 3.77 | 16.80 | 4.46 |
| Carbonic acid (free) | 28.84 | 40.00 | 4.31 | 2.52 |
| Hydrogen sulphide. | 13.09 | 5.00 | 1.80 | 0.19 |
| Sodium sulphate . | 14.25 | 10.85 | 19.94 | 18.10 |
| Aluminium sulphate | 15.60 | 9.60 | 12.38 | 8.10 |
| Silica | 15.10 | 12.10 | 22.82 | 20.20 |
| Total solids . . . | 86.81 | 52.49 | 96.47 | 79.24 |

198 THE HOT SPRINGS OF NEW ZEALAND

There are innumerable springs in the central Rotorua group, along the foreshore of the lake, which conform to the type of the Priest and Postmaster springs. Many of these have not been analysed, and have not even been named, but the first two on the following list may serve as examples.

| WAIKUPAPAPA | | | | | | Grains per gallon. |
|--------------------------|---|---|---|---|---|--------------------|
| Hydrochloric acid (free) | . | . | . | . | . | 7.49 |
| Sulphuric acid (free) | . | . | . | . | . | 4.29 |
| Total solids | . | . | . | . | . | 56.45 |

| NGARUAPUIA | | | | | | |
|--------------------------|---|---|---|---|---|-------|
| Hydrochloric acid (free) | . | . | . | . | . | 6.76 |
| Sulphuric acid (free) | . | . | . | . | . | 3.11 |
| Total solids | . | . | . | . | . | 59.50 |

| TAHEKE, ROTOITI (1908) | | | | | | |
|------------------------|---|---|---|---|---|-------|
| Sulphuric acid (free) | . | . | . | . | . | 152.0 |
| Total solids | . | . | . | . | . | 231.0 |

| HORAKIKIMUMURU, ROTOITI (1908) | | | | | | |
|--------------------------------|---|---|---|---|---|-------|
| Sulphuric acid (free) | . | . | . | . | . | 68.6 |
| Total solids | . | . | . | . | . | 130.5 |

The most remarkable acid springs of New Zealand, however, are those arising in White Island. This is the crater of an active volcano, almost flush with the waters of the Bay of Plenty. The acidity is so strong that these waters are wholly unsuitable for baths, and are more fit for commercial industrial use.

| WHITE ISLAND (Skey) | | | | | | Grains per gallon. |
|--------------------------|---|---|---|---|---|--------------------|
| Hydrochloric acid (free) | . | . | . | . | . | 9,547.0 |
| Total solids | . | . | . | . | . | 13,638.0 |

Temperature 212° F.

WHITE ISLAND LAKE (1910) (Vide also "Arsenical Waters")

| | | | | | | |
|--------------------------|---|---|---|---|---|---------|
| Aluminium sulphate | . | . | . | . | . | 1,476.3 |
| Hydrochloric acid (free) | . | . | . | . | . | 3,383.6 |
| Total solids | . | . | . | . | . | 6,469.6 |

Temperature 110° F.

The composition of this water would appear to vary considerably. Probably samples taken from various portions of the lake would vary according to their distance from the main spring, and indeed there are probably large numbers of springs of various composition feeding the lake. Again, the analysis may probably vary from year to year in accordance with varying volcanic activity. The last analysis (1910) is given in full percentages, as it not only shows this variation, but is remarkable for showing the presence of pentathionic acid, formed by the interaction of H_2S and SO_2 , a body not previously detected in mineral waters.¹

| | Per cent. |
|------------------------------|-----------|
| Ammonium chloride | 0.02730 |
| Potassium chloride | 0.16540 |
| Sodium chloride | 0.03790 |
| Potassium bromide | 0.00510 |
| Potassium iodide | trace |
| Sodium sulphate | 0.61910 |
| Magnesium sulphate | 0.39480 |
| Calcium sulphate | 0.50900 |
| Aluminium sulphate | 2.10900 |
| Ferric sulphate | 0.26000 |
| Ferrous sulphate | 0.19760 |
| Manganous sulphate | 0.00380 |
| Copper sulphate | trace |
| Molybdic acid | trace |
| Silica | 0.00800 |
| Titanium dioxide | 0.00300 |
| Boron trioxide | 0.03100 |
| Arsenious oxide | 0.00056 |
| Carbon dioxide | 0.01300 |
| Hydrochloric acid | 4.83380 |
| Pentathionic acid | 0.02400 |
| Total | 9.24236 |

WHALE ISLAND (Pond)

| | Grains per gallon. |
|--------------------------|--------------------|
| Sulphuric acid | 138.32 |
| Total solids | 250.30 |

Temperature 198° F.

¹ Report of Dr. Maclaurin, Dominion Analyst.

200 THE HOT SPRINGS OF NEW ZEALAND

ABBOTSFORD, OTAGO (1882)

| | Grains per gallon. |
|--|--------------------|
| Sulphuric acid (free and combined with iron) | 191·87 |
| Total solids | 304·01 |

OHAEWAI (1909)

| | |
|----------------|-------|
| Sulphuric acid | 108·0 |
| Total solids | 129·0 |

TAUPO DISTRICT

ROKOKAWA (Black Water) (Hector)

| | |
|--------------------------|-------|
| Hydrochloric acid (free) | — |
| Total solids | 142·4 |
| Temperature 192° F. | |

ROKOKAWA (Yellow Water) (Hector)

| | |
|--------------------------|-------|
| Hydrochloric acid (free) | — |
| Total solids | 176·0 |
| Temperature 152° F. | |

WAIKAKEI DISTRICT

Practically all the springs of the Kiriohinekei Valley are more or less acid: two are given as types.

DEVIL'S EYEGLASS (1906)

(Vide also "Chalybeate Waters")

| | Grains per gallon. |
|-----------------------|--------------------|
| Sulphuric acid (free) | 2·80 |
| Carbonic acid (free) | 7·10 |
| Total solids | 117·25 |

THE BOILERS (1906)

(Vide also "Chalybeate Waters")

| | |
|-----------------------|--------|
| Sulphuric acid (free) | 4·50 |
| Carbonic acid (free) | 7·50 |
| Total solids | 100·77 |

SULPHUR TERRACE, WAI-O-TAPU (1909)

| | |
|-----------------------|------|
| Sulphuric acid (free) | 2·5 |
| Total solids | 43·6 |
| Temperature 212° F. | |

These three last springs are, with White Island and Whale Island, important exceptions to the rule (vide p. 24) that in New Zealand all the boiling springs are alkaline.

Subclass (c), Muddy Waters

There remains a subclass of the sulphur waters which consists of mineral water containing large quantities of highly siliceous mud and pure sulphur in suspension. Strictly speaking, they should all perhaps be included in one of the foregoing classes, but they are very characteristic of the New Zealand spas, and it is practically convenient to put them in a class by themselves.

Their importance lies in the fact that they are utilized as mud baths.

In former days it was the common practice to bathe in the actual springs, or in such parts of their pools as were cool enough to permit this, and in this way the maximum therapeutic efficiency was secured; for there was the skin stimulus, not only of the emulsion of mud and sulphur and of the mineral water, but of the free gases. Such baths were very valuable, but very dangerous, and serious accidents were common. Thus the Cameron Spring was also known as the "Laughing Gas" bath, from the frequent toxic effect on bathers of inhaling a mixture of carbonic acid and sulphuretted hydrogen, and on account of their danger these baths are now very little used.

Some of them contain free mineral acids, others are neutral or only give an acid reaction from the amount of free carbonic acid they contain. Typical examples of the former are the "Coffee Pot" and the Cameron Springs, and of the latter the Sulphur Point Mud Spring, all at Rotorua.

Their waters are of the consistency of pea-soup, of a dark-brown colour, generally with an oily scum floating on the top, and their sides are composed of the dried and solidified dark-brown greasy mud such as is used for the mud baths (vide fig. 30).

COFFEE POT

| | Grains per gallon. |
|---|--------------------|
| Sodium sulphate | 23·71 |
| Hydrochloric acid (free) | 7·66 |
| Sulphuric acid (free) | 7·60 |
| Total solids (apart from mud) | 60·19 |

CAMERON SPRING

| | Grains per gallon. |
|--|--------------------|
| Sodium sulphate | 44.54 |
| Hydrochloric acid (free) | 5.92 |
| Gases abundant H_2S and CO_2 | |
| Total solids (apart from mud) | 80.50 |

SULPHUR POINT MUD SPRING (1907)

| | |
|---|--------|
| Sodium chloride | 80.85 |
| Sodium silicate | 20.30 |
| Carbonic acid (free) | 14.90 |
| Total solids (apart from mud) | 141.72 |

Below is given an analysis¹ of the muddy deposit of this spring, from which, and from similar material, the mud baths of Rotorua principally are made. It consists mainly of silica, and is noticeable in that it contains both gold and silver. On account of its interest I have given Dr. Maclaurin's percentage analysis in full :

| | Per cent. |
|------------------------------|-----------|
| Silica | 69.30 |
| Alumina | 4.52 |
| Iron oxides | 2.00 |
| Titanium oxide | 0.58 |
| Lime | 1.00 |
| Magnesia | 0.10 |
| Soda and potash | 1.30 |
| Sulphur (combined) | 1.40 |
| Sulphur (free) | 6.09 |
| Organic matter | 10.01 |
| Water | 3.70 |

Microscopic examination of the deposit showed that it consisted mainly of quartz and amorphous silica, with a little feldspar. The mud also contains 5 grains of gold and 6 dwt. 1 grain of silver per ton.

CLASS IX. ARSENICAL WATERS

There are no springs containing arsenic used for therapeutic purposes in New Zealand. Several springs contain

¹ For a percentage analysis of the solid mud which forms the basis of the mud baths see p. 88.

traces of arsenic ; others, again, reputed to do so, such as the " Arsenic Spring " in the Spa grounds at Taupo, contain none at all.

There is one spring, however, which, though its percentage of arsenic is moderate, is of so huge an output as to dwarf completely all the arsenical springs of Europe put together. This is the hot acid lake on White Island, some 15 acres in extent (vide p. 198).

The waters, however, are so highly mineralized as to be unfit for either internal or external medication.

EUROPE

LA BOURBOULE

| | Grains per gallon. |
|------------------------------|--------------------|
| Sodium chloride | 196 |
| Sodium bicarbonate | 196 |
| Sodium arseniate | 1.96 |
| Total solids | 448.00 |

Temperature 140° F.

NEW ZEALAND

WHITE ISLAND LAKE, 15 acres (1909-10)

| | |
|---------------------------|----------|
| Arsenious oxide | 0.392 |
| Total solids | 6,469.65 |

Temperature 110° F. to 212° F.

BURTON'S SPRING, TAUPU (Hector)

" Traces of arsenic."

CLASS X. BORATED WATERS

Salts of boron are not uncommon in the waters of volcanic springs, but they are rare in mineral waters used for therapeutic purposes, and but scanty reference to borated waters can be found in balneological textbooks.

In some of the waters of Italy sodium borate is present in such large quantities that the springs are exploited commercially. In Tuscany the waters are evaporated by the aid of the natural heat of fumaroles, and the extraction of the borate has proceeded on so large a scale that quite a thriving little manufacturing town has arisen.

In America there are several borated springs in California, one of which contains as much as 201·75 grains of borate per U.S. gallon. Traces of boron are found in the springs of Baden (Switzerland), but appear to be of no therapeutic importance.

In several New Zealand waters, however, the salt is present in considerable quantities and has a marked pharmacological influence.

In the earlier analyses the borates were overlooked, and it was not until the occasional inexplicable purging and irritant effect of these waters directed attention to them and brought about a fresh analysis that the boron was discovered.

Pharmacological Action.—Borates have been used as a substitute for bromides in epilepsy, but their action is uncertain and apt to be attended by uncomfortable toxic symptoms. G. Seng¹ used boracic acid and borax for reducing weight, giving small doses, gradually increased to 15 grains or 20 grains a day, but found the drug not well borne. Boracic acid has been used also in diabetes, apparently with some success, while its action as a urinary antiseptic is of course familiar. The sphere of useful action of the borates, then, would appear to be distinctly limited.

On the other hand, the toxic effects of boric acid are well known.

Cases of severe gastro intestinal disturbances in infants as a result of the too free and injudicious use of borax and honey have frequently been recorded,² and the use of boracic acid as a food preservative has been strictly regulated by Health Departments³ throughout the world. Chevalier⁴

¹ *Treatment*, August 1903, quoting *Ther. d. Gegern.*, April 1903.

² Cf. McNeill, *B.M.J.*, July 20, 1912.

³ Boric acid has an irritative effect on the alimentary tract and may produce headache, malaise, abdominal discomfort, vomiting, diarrhœa, skin eruptions, and defective assimilation of food (Report of Dr. Hamill, L.G.B. Food Dept., 1910). The *Local Government Board Circular*, 1906, lays down that boric acid in a solution of over 40 grains per gallon is injurious to infants.

⁴ *Revue Franç. de Méd. et de Chir.*, January 1905.

pointed out the danger of the drug when elimination is defective, e.g. in renal insufficiency.

On the whole, then, it would seem, in the present state of our knowledge, wiser not to use the strongly borated waters by the mouth, though of course the weaker waters such as the Rachel, which contains less than 2 grains of borate per gallon, are quite innocuous.

AMERICA

HOT BORATE SPRING, CALIFORNIA

| | Grains per U.S. gallon. |
|-------------------|-------------------------|
| Borates | 201.75 |

NEW ZEALAND

HANMER (1912-13) ¹

| | Grains per gallon. |
|-------------------------|--------------------|
| Sodium borate | 17.57 |
| Total solids | 81.68 |

"MAGNESIA SPRING," TAUPO (1913)

| | |
|-------------------------|--------|
| Sodium borate | 3.69 |
| Total solids | 108.78 |

PUKETITIRI, NAPIER (1913)

| | |
|-------------------------|-------|
| Sodium borate | 3.03 |
| Total solids | 23.64 |

WHITE ISLAND LAKE (1910)

| | |
|--------------------------|---------|
| Boron trioxide | 21.7 |
| Total solids | 6,469.6 |

TE KUITI (1913)

(Vide also "Calcic Sodid Muriated Waters")

| | |
|-------------------------|----------|
| Sodium borate | 8.05 |
| Total solids | 1,454.46 |

HIKUTAIA, OHINEMURI (1915-16)

| | |
|--------------------------------|-------|
| Sodium borate | 4.06 |
| Sodium bicarbonate | 57.82 |
| Total solids | 77.98 |
| Carbonic acid (free) | 16.24 |

MIRANDA (1919)

| | |
|-------------------------------|-------|
| Borax, crystallized | 4.9 |
| Total solids | 39.13 |

¹ Some of the original springs unconnected with the bore probably contain less borate, and in that case would be more suitable for internal administration. Further analysis is desirable to elucidate this point.

CLASS XI. TABLE WATERS

This is a somewhat ill-defined group of waters, characterized by feeble mineralization, and usually by the presence of a considerable amount of carbonic acid gas, either artificially prepared or obtained from the same spring as the water and bottled with it. As the name implies, such waters are not intended primarily for medical purposes, and are valued rather as a pleasant drink whose purity is above suspicion.

In New Zealand omnipotent tea has largely ousted water from the dietary of teetotalers, and, for the rest, table waters are judged chiefly from the point of view of their good or bad admixture with whisky. It is essential, therefore, that the mineralization should not be too strong, and more particularly that there should be as little iron present as possible, as this blackens with the tannic acid derived from the spirit casks, or with that more abundantly present in wines.

Apart from this use, table waters have an undoubted therapeutic application. They are generally weakly alkaline, the salts of sodium, calcium, or magnesium preponderating, and, rightly used, are of service in dyspepsia. The carbonic acid they contain stimulates the gastric mucous membrane and promotes peristalsis. As a rule, too, they are diuretic, and their essential use in medicine is to act as a pleasant flush to the system.

There are very many springs in New Zealand that would make ideal table waters, but, for reasons already given, the demand is comparatively limited, and some of those waters that are bottled are, by reason of their high mineralization, rather medicinal than true table waters. Indeed, it is obvious that there can be no hard-and-fast line, and that such waters must at one end shade off gradually into the muriated, the alkaline, or the calcareous classes.

From what has been said already (p. 27), it is evident that the waters of siliceous districts should form an ideal

basis for a table water. They are remarkably pure, of a characteristic clear, sparkling appearance, and conspicuously palatable. Such a spring as Hamurana, which is the uprising of an underground river, whose waters are absolutely pure and abundant enough to supply the table water of a continent, must surely some day be bottled for the needs of less fortunate districts: and there are many such springs flowing into the Rotorua chain of lakes.

It should be added that several of the most famous table waters of Europe are "doctored," generally for the purpose of removing traces of iron. The perfect table water should be absolutely untouched and should be bottled with its own carbonic acid gas.

One or two of the New Zealand waters fulfil these conditions.

EUROPE

SELTZERS WATER (Seltzer Water)

| | Grains per gallon. |
|---------------------------------|--------------------|
| Sodium chloride | 140·0 |
| Sodium bicarbonate | 70·0 |
| Calcium bicarbonate | 35·0 |
| Magnesium bicarbonate | 17·5 |

NEW ZEALAND

WAIRONGOA

| | |
|---------------------------------|--------|
| Sodium chloride | 22·73 |
| Sodium bicarbonate | 20·91 |
| Sodium sulphate | 14·70 |
| Calcium bicarbonate | 67·86 |
| Magnesium bicarbonate | 35·89 |
| Total solids | 165·75 |

Together with a large amount of free carbonic acid gas, which is bottled with the water.

Several other waters already classed under other headings, as alkaline, muriated, magnesia, etc., are bottled as table waters. Some of these, such as the alkaline Te Aroha and Puriri waters, are really too heavily mineralized to be classed as simple table waters; others, such as the magnesia waters of Te Aroha and the calcareous waters of Kamo, contain

appreciable quantities of iron. Their analyses have been already given.

CLASS XII. MUDS

Although it is not strictly logical to class the muds under the head of "waters," yet, as they are used in similar fashion for baths, it is practically convenient.

As we have already seen (pp. 47-48), the Thermal District is honeycombed by boiling mud springs. These are caused by the escape of steam through a stratum of clay. The steam, with its concomitant hydrogen sulphide and sulphurous acid, softens the clay into a smooth paste, while the sulphur compounds are partially oxidized into sulphuric acid and other sulphates, with the deposition of sulphur.

As a result we get a bland siliceous mass, acid in reaction, and containing a good deal of free sulphur.

The analyses of different samples vary slightly, and the general appearance of the different muds varies a good deal, depending as it does upon the nature of the clay. Thus, within a few yards of each other, we may find boiling mud pools black, grey, red, or nearly white, for the clays of the district are rainbow-hued. The most common colour, however, is a dark grey-brown.

With certain consistencies of mud the material, instead of forming boiling cauldrons, is heaped up into miniature volcanic cones (vide fig. 35).

Such muds are absolutely free from grit, and, as they dry on the skin, have a feeling that can only be described as "sebaceous." They readily wash off, and leave the skin soft and hyperæmic. Their action in baths is much that of the peat baths of Europe, which also are acid—that is to say, they are soothing and pain-relieving, and at the same time stimulant to the skin circulation. They may be used diluted as immersion baths, or in full strength in poultice form, and are indicated in arthritic and other painful conditions, whether of rheumatic, gouty, or traumatic origin, and perhaps most of all in chronic disease of the skin.

The above description is of the usual mud to be found throughout the Thermal District. For convenience of transport, the dried deposit from the sides of the springs is artificially broken down by steam for the baths at Rotorua. This deposit, as we have shown elsewhere, is somewhat more radio-active than the fresh hot mud in the spring, but the activity is hardly enough to be of any probable therapeutic importance.

Analysis of Mud : Subclass (a), Siliceous Sulphur Mud

- (i) Direct from hot spring.
(ii) Dry mud as used at baths.

AIR-DRIED SAMPLES

| | | (i) | (ii) |
|--------------------------|-----------------------------------|---------------|--------------|
| Silica | SiO ₂ | 61.65 | 48.52 |
| Alumina | Al ₂ O ₂ | 21.84 | 28.45 |
| Iron oxide | Fe ₂ O ₃ | 0.56 | 0.40 |
| Titanium dioxide | Ti ₂ O | 0.40 | 0.40 |
| Lime | CaO | 0.30 | 0.40 |
| Magnesia | MgO | 0.20 | 0.23 |
| Alkalies | Na ₂ OK ₂ O | 0.50 | nil |
| Free sulphur | — | 0.85 | 0.08 |
| Sulphuric anhydride | SO ₂ | 2.80 | 0.81 |
| Water and organic matter | — | 11.05 | 20.46 |
| | | <u>100.15</u> | <u>99.75</u> |

Both samples were examined for gold and silver with the following results :

| | (i) | (ii) |
|------------------|---------------|------|
| | Grs. per ton. | |
| Gold | 0.5 | nil |
| Silver | 7 0 | nil |

Subclass (b), Mercurial Mud

There is a very remarkable group of springs at Ohaewai in the north, near the Bay of Islands. A number of boiling or nearly boiling springs of sulphuretted, muriated, alkaline, and acid waters arise in the midst of the old

workings of a mercury mine, itself desolate in a setting of old gum fields.¹

The hot water and steam have decomposed the cinnabar ore alongside, and mercury is deposited in visible metallic globules in the hot mud. This mud, used by the Maori as a parasiticide, has obvious possibilities for inunction in syphilis, more especially in conjunction with the hot sulphur baths alongside.

At present these baths are unused, but we can imagine how such a combination would excite the envy of the authorities at Aachen!

The analysis of the waters is as follows:

OHAEWAI (1908)

| | (i) Spring No. 1. Grains per gall. | (ii) Shaft Spring. Grains per gall. | (iii) 2 Mercury Spring. Grains per gall. | (iv) Petroleum Spring Grains per gall. |
|---|--|---|--|--|
| Sodium chloride . | 87.0 | 1.1 | 29.9 | 1.5 |
| Potassium chloride . | 12.7 | — | 2.1 | — |
| Sodium sulphate . | — | 20.2 | 13.3 | 6.5 |
| Potassium sulphate . | — | 6.3 | — | |
| Calcium sulphate . | 3.4 | 6.7 | 8.4 | 2.4 |
| Magnesium sulphate . | 2.4 | 3.6 | 3.1 | 0.3 |
| Ferrous sulphate . | — | 4.1 | — | 0.1 |
| Sodium bicarbonate . | 65.0 | — | — | — |
| Ferrous bicarbonate . | 1.0 | — | — | — |
| Silica | — | 3.6 | — | 10.2 |
| Sodium silicate . | 7.1 | — | — | — |
| Total solids . | 178.6 | 45.6 | 56.8 | 21.0 |
| Free H ₂ SO ₄ . . . | — | 50.9 | — | 108.0 |
| „ CO ₂ | — | 49.5 | — | — |
| „ H ₂ S | — | 1.1 | — | — |

¹ Large areas in the peninsula north of Auckland have been dug over and riddled with spade and spear in the search for the valuable kauri gum deposited by the primeval kauri forests. Kauri gum is still a large industry in "the North."

² Metallic mercury is deposited in the mud surrounding this spring.

CHAPTER XIV

THE CLIMATE OF NEW ZEALAND ¹

THE climate of New Zealand is spoken of in popular and general terms as equable, mild, and salubrious, but such a summary does not convey an adequate idea of variations that exist in a country stretching as it does, north and south, for nearly a thousand miles, and distinctly differentiated by lofty mountain chains. Another fact which must also be borne in mind is that the greater part of the North Island is controlled by a different system of circulation from that which dominates conditions in the parts about Cook Strait and the South Island. The former is subject to ex-tropical disturbances, and the latter more to westerly and Antarctic "lows," which travel along the latitudes of the "forties" with their prevailing westerly winds.

The climate of the Auckland Province, speaking generally, combines degrees of warmth and humidity agreeable by day and comfortable by night. North of Auckland City conditions are almost sub-tropical, and in summer balmy easterly breezes prevail, and are responsible for delightful conditions. In winter the winds are more north and west, while changes to the south-east or south-west mostly account for the rainfall. Cumulus clouds are frequently formed in the afternoons, and, while tempering the heat of the day, also cut down sunshine records somewhat, but add considerably to the beauty of land- and seascape. Southward of Auckland the climate is more varied, the west coast experiencing more rain, while the central parts are warmer

¹ This chapter has been kindly contributed by the Rev. D. C. Bates, Director of the Dominion Meteorological Office.

212 THE HOT SPRINGS OF NEW ZEALAND

AUCKLAND

| Month. | Mean temperatures for 56 years. | | | Mean rainfall for 67 years. | | Mean sunshine for 10 years. | |
|------------|---------------------------------|----------|----------|-----------------------------|-------|-----------------------------|--------------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. | Days. | | |
| | | | | | | Inches. | Hours. Mins. |
| January . | 73·7 | 58·9 | 66·5 | 2·54 | 10·3 | 217 | 25 |
| February . | 74·3 | 59·6 | 67·1 | 2·96 | 9·6 | 176 | 37 |
| March . | 72·0 | 57·7 | 65·0 | 3·02 | 11·1 | 171 | 58 |
| April . | 67·8 | 54·6 | 61·2 | 3·30 | 13·9 | 139 | 8 |
| May . | 62·7 | 50·5 | 56·7 | 4·45 | 18·3 | 129 | 17 |
| June . | 59·2 | 47·8 | 53·5 | 4·72 | 19·4 | 113 | 45 |
| July . | 57·6 | 46·0 | 51·8 | 5·15 | 21·0 | 114 | 57 |
| August . | 58·2 | 46·0 | 52·2 | 4·24 | 19·6 | 137 | 11 |
| September | 60·7 | 48·4 | 54·7 | 3·61 | 17·6 | 136 | 48 |
| October . | 63·5 | 50·7 | 57·3 | 3·60 | 16·4 | 159 | 42 |
| November | 67·0 | 53·3 | 60·2 | 3·28 | 14·6 | 184 | 23 |
| December . | 70·9 | 56·7 | 63·9 | 2·80 | 11·5 | 213 | 52 |
| Year . | 65·6 | 52·5 | 59·2 | 43·67 | 183·3 | 1,895 | 3 |

ROTORUA

| Month. | Mean temperatures for 32 years. | | | Mean rainfall for 34 years. | | Mean sunshine for 8 years | |
|------------|---------------------------------|----------|----------|-----------------------------|-------|------------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. | Days. | | |
| | | | | Inches. | | Hours. | Mins. |
| January . | 75·5 | 52·3 | 63·9 | 3·95 | 9·5 | 253 | 39 |
| February . | 74·9 | 52·2 | 63·4 | 3·83 | 8·7 | 190 | 59 |
| March . | 71·8 | 49·4 | 60·6 | 3·68 | 9·7 | 191 | 24 |
| April . | 66·0 | 45·4 | 55·6 | 4·26 | 10·8 | 160 | 23 |
| May. . | 60·0 | 40·7 | 50·3 | 5·52 | 12·5 | 141 | 41 |
| June . | 55·6 | 38·2 | 46·8 | 4·86 | 12·9 | 119 | 40 |
| July. . | 54·2 | 37·0 | 45·5 | 5·29 | 14·1 | 127 | 14 |
| August . | 56·1 | 37·5 | 46·7 | 5·01 | 13·4 | 148 | 15 |
| September | 59·6 | 40·8 | 50·2 | 5·14 | 14·4 | 156 | 5 |
| October . | 63·9 | 44·0 | 54·0 | 4·89 | 14·1 | 187 | 5 |
| November | 68·3 | 46·7 | 57·5 | 4·09 | 12·8 | 213 | 44 |
| December . | 72·8 | 49·6 | 61·1 | 3·63 | 9·7 | 228 | 28 |
| Year . | 64·9 | 44·5 | 54·6 | 54·15 | 142·6 | 2,118 | 37 |

in the day and considerably colder at night. In the winter months frosts, which are unknown farther north, now and then occur in the hours of darkness. Eastward from Rotorua (the great health resort and centre of the thermal region) is to be found one of the most genial climates in the world,

and Tauranga and Opotiki have charms all their own, especially for their weather and the fruits which ripen to perfection in these regions.

The monthly and annual means of the temperature, rainfall, and sunshine of Auckland are shown in the table on p. 212.

The Hawke's Bay Province is one of the richest in New Zealand and is favoured with a pleasant climate, being sheltered from westerly winds, though occasionally they are of the warm and dry (Foehn) type. It is rather dry, but ex-tropical disturbances are occasionally responsible for heavy downpours, while, though the number of "days with rain" is less and sunshine above that of other parts, the rainfall is still a good one and fairly regular throughout the year, though some seasons have been notably dry. The meteorological records of Napier show reliable normals for the coastal districts. Inland, the country is rather mountainous and less mild.

HAWKE'S BAY PROVINCE

| Month. | Mean temperatures for 29 years. | | | Mean rainfall for 15 years. | | Sunshine for 13 years. | |
|-------------|---------------------------------|----------|----------|-----------------------------|-------|---------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. | Days. | | |
| | | | | Inches. | | Hours. | Mins. |
| January . | 75·9 | 57·0 | 66·4 | 1·64 | 6·4 | 281 | 5 |
| February . | 74·5 | 56·7 | 65·6 | 2·47 | 6·4 | 212 | 56 |
| March . | 71·2 | 54·7 | 63·0 | 3·86 | 9·3 | 211 | 49 |
| April . | 67·2 | 50·4 | 58·7 | 2·58 | 7·9 | 195 | 27 |
| May . | 61·7 | 46·3 | 54·0 | 4·42 | 9·7 | 159 | 20 |
| June . | 58·0 | 42·3 | 50·1 | 2·59 | 7·9 | 165 | 40 |
| July . | 56·5 | 41·6 | 49·0 | 3·95 | 10·8 | 149 | 27 |
| August . | 57·9 | 42·1 | 50·0 | 3·13 | 10·8 | 187 | 14 |
| September . | 62·3 | 45·2 | 53·7 | 1·83 | 8·3 | 220 | 11 |
| October . | 66·4 | 48·7 | 57·5 | 2·44 | 9·1 | 235 | 38 |
| November . | 69·6 | 51·8 | 60·7 | 2·17 | 8·4 | 245 | 42 |
| December . | 73·1 | 55·3 | 64·2 | 2·07 | 7·1 | 275 | 38 |
| Year . | 66·2 | 49·3 | 57·7 | 33·15 | 102·1 | 2,540 | 7 |

Wellington, the capital city, as disclosed by its meteorological records, has a mean climate for the whole Dominion.

Wellington occupies a central position and is situated near Cook Strait, which divides the two main Islands. It has a somewhat changeable but temperate climate, and, though occasionally subject to disturbances from warmer regions, is usually controlled by the terrestrial wind-currents which have a westerly direction round the world in the latitude of the "forties." It is popularly regarded as a rather windy spot, for high winds are frequently experienced, but they hardly ever reach hurricane force. Its windiness owes much to local configuration, for places quite near Wellington experience very little wind, and to compensate for this rather disagreeable element there is a bountiful sunshine, averaging 2,038 hours per annum, and there is a plentiful rainfall, amounting to nearly 50 inches.

The climatic means for Wellington are as follows :

| Month. | Mean temperatures for 56 years. | | | Mean rainfall for 58 years. | | Mean sunshine for 13 years. | |
|------------|---------------------------------|----------|----------|-----------------------------|-------|-----------------------------|-------|
| | Max. °F. | Min. °F. | Mean F°. | Rainfall. | Days. | | |
| | | | | Inches. | | Hours. | Mins. |
| January . | 69.4 | 55.8 | 62.5 | 3.28 | 10.4 | 232 | 30 |
| February . | 69.2 | 55.7 | 62.5 | 3.23 | 9.1 | 208 | 50 |
| March . | 66.8 | 54.2 | 60.5 | 3.29 | 11.7 | 176 | 37 |
| April . | 62.8 | 51.3 | 57.0 | 3.89 | 13.2 | 153 | 58 |
| May . | 58.3 | 47.3 | 52.8 | 4.81 | 16.7 | 130 | 50 |
| June . | 54.7 | 44.3 | 49.5 | 4.93 | 17.3 | 103 | 39 |
| July . | 53.1 | 42.3 | 47.7 | 5.81 | 18.4 | 101 | 31 |
| August . | 54.4 | 42.8 | 48.6 | 4.46 | 17.0 | 142 | 2 |
| September | 57.4 | 45.7 | 51.6 | 4.09 | 15.2 | 161 | 29 |
| October . | 60.3 | 48.3 | 54.3 | 4.13 | 14.1 | 178 | 32 |
| November | 63.4 | 50.4 | 56.9 | 3.48 | 12.8 | 207 | 3 |
| December . | 66.9 | 53.8 | 60.3 | 3.21 | 12.1 | 240 | 55 |
| Year . | 61.4 | 49.3 | 55.3 | 48.61 | 168.0 | 2,037 | 55 |

Between Wellington and Taranaki, following the Taranaki Bight, is probably one of the most fertile and agreeable regions in Australasia ; but inland, though very productive, conditions are not so favourable.

Taranaki has a rather heavy rainfall, and in most parts of this region the grass is always green. Its climate is mild,

and cattle winter in the open. Wanganui and Palmerston North districts (which lie between Wellington and Taranaki) have less rainfall than either Wellington or Taranaki, and have advantages over other parts of both Wellington and Taranaki.

It may be useful to make a comparison between the records of Wellington and Campden Hill, London :

CAMPDEN HILL, LONDON

| Month. | Mean max. °F. | Mean min. °F. | 35 years. Mean °F. |
|-----------------|---------------|---------------|--------------------|
| January . . . | 43·5 | 34·0 | 38·8 |
| February . . . | 45·6 | 34·4 | 40·0 |
| March . . . | 50·1 | 35·6 | 42·9 |
| April . . . | 57·4 | 39·4 | 48·4 |
| May . . . | 64·9 | 45·2 | 55·1 |
| June . . . | 70·9 | 51·0 | 61·0 |
| July . . . | 74·1 | 54·4 | 64·3 |
| August . . . | 72·6 | 53·7 | 63·2 |
| September . . . | 67·4 | 49·8 | 58·6 |
| October . . . | 57·5 | 43·9 | 50·7 |
| November . . . | 49·7 | 38·9 | 44·3 |
| December . . . | 45·1 | 35·8 | 40·5 |
| Year . . . | 58·2 | 43·0 | 50·6 |

MOUMAHAKI (TARANAKI)

| Month. | Mean temperatures for 14 years. | | | Mean rainfall for 15 years. | | Mean sunshine for 13 years. | |
|--------------|---------------------------------|----------|----------|-----------------------------|-------|-----------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Raintall. | Days. | | |
| | | | | Inches. | | Hrs. | Mins. |
| January . . | 70·0 | 53·3 | 61·6 | 3·03 | 9·5 | 236 | 12 |
| February . . | 70·8 | 53·3 | 62·1 | 2·79 | 8·0 | 186 | 58 |
| March . . | 69·6 | 52·4 | 61·0 | 3·85 | 9·1 | 179 | 35 |
| April . . | 64·4 | 48·2 | 56·3 | 3·94 | 13·1 | 152 | 53 |
| May . . | 59·1 | 44·1 | 51·6 | 4·17 | 14·0 | 121 | 22 |
| June . . | 55·1 | 42·5 | 48·8 | 4·39 | 15·2 | 99 | 53 |
| July . . | 53·7 | 40·9 | 47·3 | 4·27 | 16·9 | 106 | 54 |
| August . . | 55·5 | 41·8 | 48·7 | 3·67 | 14·6 | 138 | 51 |
| September . | 58·8 | 44·8 | 51·8 | 4·04 | 14·2 | 150 | 5 |
| October . . | 61·8 | 47·0 | 54·3 | 4·41 | 15·0 | 163 | 21 |
| November . | 64·6 | 49·1 | 56·8 | 3·61 | 12·8 | 168 | 42 |
| December . | 68·2 | 50·9 | 59·5 | 3·59 | 12·1 | 231 | 12 |
| Year . . | 62·6 | 47·4 | 55·0 | 45·76 | 154·5 | 1,935 | 58 |

Nelson and Marlborough are highly favoured regions with regard to sunshine and shelter from marine winds. Long ago Bishop Selwyn said: "No one knows what the climate is till he has basked in the almost perpetual sunshine of Tasman's Gulf, with a frame braced and invigorated to the full enjoyment of heat by the wholesome frost or cool snowy breeze of the night before."

Pastoral and agricultural industries are thriving, and the Province of Nelson is also famous for its fruit cultures—apples especially being celebrated for their variety, colour, and flavour. The rainfall about Nelson is very reliable and averages from 35 to 45 inches per annum. Marlborough is also a sunny province, and its rainfall averages from 25 to 30 inches.

The records for Nelson are as follows:

| Month. | Mean temperatures for 31 years. | | | Mean rainfall for 37 years. | |
|-------------|---------------------------------|----------|----------|-----------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. | Days. |
| | | | | Inches. | |
| January . | 75.5 | 53.8 | 64.6 | 2.66 | 7.9 |
| February . | 74.6 | 53.9 | 64.1 | 2.68 | 6.6 |
| March . | 71.4 | 51.4 | 61.3 | 2.99 | 8.9 |
| April . | 66.5 | 47.4 | 57.0 | 2.87 | 9.6 |
| May . | 60.3 | 42.5 | 51.3 | 3.20 | 10.0 |
| June . | 56.2 | 38.9 | 47.5 | 3.82 | 10.1 |
| July . | 54.7 | 37.7 | 46.2 | 3.61 | 11.2 |
| August . | 56.7 | 38.6 | 47.6 | 3.01 | 10.5 |
| September . | 60.8 | 42.2 | 51.5 | 3.70 | 12.2 |
| October . | 64.9 | 45.0 | 55.0 | 3.24 | 11.9 |
| November | 69.0 | 48.4 | 58.7 | 2.91 | 11.3 |
| December . | 72.0 | 51.4 | 61.8 | 2.68 | 8.8 |
| Year . | 65.2 | 45.9 | 55.6 | 37.37 | 119.0 |

The climate of Westland is influenced by its position with regard to the prevailing westerly winds, its proximity to the sea, from which these winds blow across the Tasman Sea, and the mountainous character of its eastern half. The rainfall, as might be expected, is heavy, and ranges from about 70 inches per annum in the north on the coast to as much as 200 inches in the mountainous country. The weather

changes are chiefly due to atmospheric depressions, with lowest pressures passing south of the Dominion. Cyclones centred in the north, while bringing heavy rains to the North Island and the East Coast portions of the South, do not, as a rule, affect Westland, as easterly winds which then prevail are not conducive to cloud formation in this province. Sunshine averages 1,858 hours a year, and, though not so abundant as in East Coast districts, is a good average amount considering the rainfall. Westland is noted for a clear, beautiful atmosphere during fair-weather periods.

HOKITIKA

| Month. | Mean temperatures for 34 years. | | | Mean rainfall for 40 years | | Sunshine for 7 years. | |
|------------|---------------------------------|----------|----------|----------------------------|-------|-----------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. | Days. | | |
| | | | | Inches. | | Hours. | Mins. |
| January . | 67·9 | 53·7 | 60·8 | 9·92 | 12·2 | 189 | 27 |
| February . | 68·4 | 53·3 | 60·8 | 7·54 | 11·0 | 174 | 29 |
| March . | 66·2 | 51·3 | 58·7 | 9·85 | 13·7 | 176 | 38 |
| April . | 62·7 | 47·2 | 54·9 | 8·94 | 14·9 | 131 | 10 |
| May . | 58·3 | 42·5 | 50·4 | 10·03 | 15·5 | 139 | 23 |
| June . | 54·9 | 39·1 | 47·0 | 9·90 | 15·3 | 101 | 15 |
| July . | 52·9 | 36·7 | 44·8 | 9·05 | 16·3 | 105 | 1 |
| August . | 54·6 | 38·1 | 46·3 | 9·02 | 15·8 | 150 | 11 |
| September | 57·8 | 42·4 | 50·1 | 9·37 | 16·5 | 133 | 51 |
| October . | 59·8 | 45·7 | 52·7 | 11·50 | 18·7 | 161 | 35 |
| November | 62·3 | 48·4 | 55·3 | 10·31 | 17·0 | 174 | 5 |
| December | 66·3 | 52·2 | 59·2 | 10·54 | 15·8 | 220 | 33 |
| Year . | 60·9 | 45·8 | 53·3 | 105·62 | 152·2 | 1,857 | 38 |

The district of Canterbury comprises a variety of topographical features. A plain stretches over a hundred miles from north-east to south-west with a maximum width of about 40 miles, from the East Coast to the foothills to the westward. The latter merge into the mountainous country culminating in the main range of the Southern Alps, which divide the provinces of Canterbury and Westland, and afford a protection from the heavily moisture-laden north-westerly winds. The rainfall of the Canterbury Plains is, in consequence, much restricted, the average being about 26 inches.

There is, however, a remarkable progressive increase from east to west, as is shown by the records. At Christchurch the mean is 25·13 inches, at Mt. Torlesse Station (near Springfield) 39·86 inches. The climate of Canterbury might almost be described as continental in type, with large extremes of temperature between summer and winter and day and night. Except in the three summer months, frosts are numerous, and even in the early spring and late autumn they are at times severe enough to damage vegetation of a tender nature. In summer day temperatures of over 90° in the shade are sometimes experienced. Both with regard to climate and soil "the Plains" have proved most suitable for agricultural farming, and much of the district is capable of growing splendid cereal and root crops. The prevailing winds in Canterbury are north-east and south-west, while north-westerlies are not, as often supposed, of frequent occurrence. They are most common in the springtime, and being dry and warm they have a somewhat enervating effect, though in winter-time they come as a welcome change from the keen temperatures then generally ruling. The bright sunshine as recorded at Lincoln shows a daily average for the year of 5·8 hours.

CHRISTCHURCH

| Month. | Mean temperatures for 23 years. | | | Mean rainfall for 42 years. | |
|-------------|---------------------------------|----------|----------|-----------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. Inches. | Days. |
| January . | 70·7 | 52·6 | 61·6 | 2·06 | 9·1 |
| February . | 69·3 | 52·6 | 60·9 | 1·87 | 7·9 |
| March . | 66·4 | 50·0 | 58·2 | 2·21 | 9·5 |
| April . | 61·8 | 45·1 | 53·4 | 1·92 | 9·5 |
| May . | 56·1 | 40·1 | 48·1 | 2·56 | 11·6 |
| June . | 50·9 | 36·0 | 43·4 | 2·67 | 12·4 |
| July . | 49·9 | 34·9 | 42·4 | 2·87 | 13·4 |
| August . | 52·2 | 36·2 | 44·2 | 1·79 | 11·0 |
| September . | 57·2 | 40·5 | 48·8 | 1·69 | 9·9 |
| October . | 62·2 | 43·6 | 52·9 | 1·64 | 9·3 |
| November . | 66·0 | 47·4 | 56·7 | 1·85 | 10·3 |
| December . | 69·8 | 51·4 | 60·6 | 2·11 | 9·5 |
| Year . | 61·0 | 44·2 | 52·6 | 25·23 | 123·4 |

The chief health resort of the South Island, Hanmer Spa, is in North Canterbury, situated on a small plateau. On account of its altitude, 1,120 feet, it enjoys an invigorating climate, with a mean annual temperature of only about one degree below that of Christchurch. Owing to its elevated position and nearness to the mountains, Hanmer is, in some winter seasons, subject to rather severe snow-storms such as are never experienced on the Canterbury Plains.

The mean annual rainfall is 38·15 inches, and the mean total sunshine 1,992 hours.

The surrounding country is used for sheep grazing, the pasture being chiefly the native tussock grass, which is common to all the uncultivated hill country of Canterbury.

Otago, as the southernmost part of New Zealand is now known, is very diversified both as regards its physical features and its climate. Inland, in Central and North Otago, the climate is dry and clear—hot in summer and cold in winter. The rainfall for this district averages from 13 to 20 inches. Near the coast in the Dunedin district the rainfall is more plentiful, averaging from 30 to 40 inches per annum, a good deal of which falls in light, drizzling rains. The records for Dunedin are as follows :

| Month. | Mean temperatures for 55 years. | | | Mean rainfall for 62 years. | |
|-------------|---------------------------------|----------|----------|-----------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. Inches. | Days. |
| January . | 66·4 | 49·5 | 57·0 | 3·40 | 14·2 |
| February . | 65·7 | 49·4 | 56·6 | 2·79 | 11·5 |
| March . | 62·9 | 47·8 | 55·3 | 2·96 | 12·8 |
| April . | 60·3 | 44·7 | 51·6 | 2·72 | 12·8 |
| May . | 53·3 | 41·0 | 47·0 | 3·31 | 13·7 |
| June . | 49·3 | 38·4 | 43·1 | 3·10 | 12·9 |
| July . | 47·5 | 36·9 | 41·5 | 3·07 | 13·2 |
| August . | 49·9 | 37·7 | 43·1 | 3·09 | 12·7 |
| September . | 53·9 | 40·7 | 47·0 | 2·71 | 12·6 |
| October . | 59·0 | 42·7 | 50·8 | 3·05 | 14·1 |
| November . | 61·4 | 44·9 | 53·1 | 3·23 | 14·0 |
| December . | 64·5 | 47·9 | 55·3 | 3·52 | 14·5 |
| Year . | 57·8 | 43·5 | 50·1 | 36·95 | 159·0 |

220 THE HOT SPRINGS OF NEW ZEALAND

Queenstown, on Lake Wakatipu, amongst the mountains, at an elevation of over 1,000 feet, furnishes the following averages :

| Month. | Mean temperatures for 9 years. | | | Mean rainfall for 30 years. | |
|------------|--------------------------------|----------|----------|-----------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. | Days. |
| | | | | Inches. | |
| January . | 70·4 | 49·9 | 60·1 | 2·82 | 8·8 |
| February . | 70·2 | 49·6 | 59·9 | 1·82 | 5·6 |
| March . | 66·4 | 47·9 | 57·1 | 2·55 | 7·2 |
| April . | 59·1 | 43·8 | 51·5 | 2·97 | 7·9 |
| May . | 51·8 | 38·6 | 45·2 | 2·63 | 7·5 |
| June . | 45·9 | 33·7 | 39·7 | 2·39 | 6·9 |
| July . | 43·3 | 31·8 | 37·5 | 1·89 | 5·9 |
| August . | 47·3 | 33·8 | 40·6 | 1·82 | 6·2 |
| September. | 54·3 | 38·7 | 46·5 | 2·60 | 7·5 |
| October . | 59·8 | 42·1 | 50·9 | 3·69 | 9·1 |
| November . | 63·2 | 44·5 | 53·8 | 2·74 | 8·4 |
| December . | 68·0 | 49·2 | 58·6 | 2·44 | 8·1 |
| Year . | 58·3 | 42·0 | 50·1 | 30·36 | 89·1 |

At Invercargill, the chief town of Southland, the averages are as follows :

| Month. | Mean temperatures for 11 years. | | | Mean rainfall for 26 years. | |
|------------|---------------------------------|----------|----------|-----------------------------|-------|
| | Max. °F. | Min. °F. | Mean °F. | Rainfall. | Days. |
| | | | | Inches. | |
| January . | 65·8 | 48·3 | 57·0 | 4·28 | 15·8 |
| February . | 65·7 | 47·6 | 56·6 | 2·86 | 11·7 |
| March . | 64·4 | 46·0 | 55·2 | 3·57 | 14·0 |
| April . | 59·1 | 42·7 | 50·9 | 4·37 | 16·7 |
| May . | 53·5 | 37·7 | 45·6 | 4·59 | 17·4 |
| June . | 49·7 | 36·2 | 42·9 | 3·48 | 15·9 |
| July . | 48·4 | 34·0 | 41·2 | 3·43 | 15·8 |
| August . | 52·1 | 36·1 | 44·1 | 3·39 | 14·6 |
| September. | 56·7 | 39·0 | 47·8 | 3·09 | 13·7 |
| October . | 59·5 | 42·8 | 51·1 | 4·75 | 17·2 |
| November . | 61·0 | 43·6 | 52·3 | 4·45 | 17·6 |
| December . | 63·8 | 46·2 | 55·0 | 4·33 | 15·5 |
| Year . | 58·3 | 41·7 | 50·0 | 46·59 | 185·9 |

The average rainfall of Southland is between 40 and 50 inches, but towards Queenstown the rainfall is between 30 and 40 inches. The rainfall is well distributed throughout the year, but there is less wind in winter than in summer.

Stewart Island has a wonderfully mild and moist climate, especially on its eastern side, with an average rainfall of 65·18 inches.

PART III

BALNEOLOGICAL PRINCIPLES

CHAPTER XV

SPA TREATMENT

Indications for Spa Treatment.—Treatment at a mineral-water health resort, while useful in a limited number of sub-acute conditions, is indicated more especially in *chronic* disease—chronic affections of the joints, of the muscles, of the circulatory system, of the nervous system, of the digestive tract, and of the skin, and in cases of chronic toxæmia generally.

It is also of special service in those numerous cases in which the condition displays so slight a departure from the normal, or perhaps it would be more correct to say so subtle a departure from the normal, that one cannot label the illness, and indeed hesitates to apply the term “disease” at all.

Yet, just as measles, taken in the aggregate, is a more serious menace to the human race than, say, plague, so these subtle and apparently trivial departures add perhaps more to the sum-total of human misery and human inefficiency than do the more dramatic departures from health which we docket as distinct diseases.

If one takes a dispassionate survey of the whole realm of medicine and surgery, it will be at once conceded that acute disease tends to monopolize the attention of our profession; that the keenest interest and the most determined effort are called forth by the acute case; that when a case degenerates into the chronic stage, interest speedily declines, and the fight with disease is carried on in but half-hearted fashion. It is natural, and perhaps inevitable, that this should be so. To a minor degree we see the same

thing in the rivalry between medicine and surgery: the direct methods, the tangible and often brilliant results of the surgeon, appeal to an ever-increasing army of aspirants.

But however improved our methods, however brilliant our results, there yet remains that great multitude of chronic sufferers for whom treatment still seems so depressingly impotent—the great dull, hopeless mass that eventually fills the workhouse infirmaries or saddens and cripples countless households.

Apart altogether from the point of view of the individual sufferer, however, the economic feature is one of the utmost importance.

The man or woman of forty, crippled by chronic disease to a premature old age of work-sterility, is a loss of earning power to, as well as a direct burden upon, the community at large, and no effort can be too great, no sacrifice too heavy, which will lighten this burden. Apart from hygienic and preventive measures, which, of course, must take precedence of any remedial ones, balneological treatment, combined with physical treatment generally, is the most potent weapon at our disposal for combating this evil.

Until comparatively recent years spa treatment has been largely, if not wholly, empirical; and while universal experience has proved its beneficial results, how and to what extent the mineral water as such has been the responsible factor, and how far the other factors, such as rest, change, diet, and so forth, should be credited, have been questions discussed with some scepticism.

In part this scepticism has been due to distrust of the popular empiric use of mineral waters, in part, it must be confessed, to our own loose terminology in the use of such words as "rheumatism," but most of all perhaps to the omission of the study of hydrology from the already overburdened course of the medical student.

Thus, while admitting that some of this is healthy scepticism, it must also be admitted that much of it is based on nothing more than a confessed ignorance of the subject,

and therefore, after going into a detailed account of the mineral waters of New Zealand, and of the treatment offered at its spas, it would seem not out of place to give a brief review of the science on which that treatment is based. The more thoroughly and carefully we examine the principles of medical hydrology the more clearly we shall see that balneology has a rational basis—that it rests on physiological data, on laws whose working we can follow and whose results we can forecast.

As we examine the phenomena we shall see that the treatment is essentially an *alterative* one—that all its processes are conceived with the one fundamental idea of influencing metabolism; and if we hold, as it would seem that almost necessarily we must hold, that at any rate the vast bulk of chronic disease is due to chronic abnormality of metabolism—for, even in cases of definite invasion by micro-organisms it is some preceding metabolic fault which has rendered that invasion possible—then such treatment is clearly indicated.

The principal factors in a cure at a watering-place are :

1. Mineral-water treatment.
2. Accessory physical treatment.
3. Diet and regulation of habits.
4. Rest.
5. Change of environment.
6. Suggestion.

Lastly, there is one factor—one most important factor—in the system of spa treatment, and that is the spa physician himself. Thousands of cases of chronic disease pass through his hands in the course of years of practice, and it would be strange indeed if he did not come to have a special knowledge of these diseases, and opportunities for diagnosis denied to most. While on the one hand it is his duty to respect the confidence of the patient's own physician by never questioning before the patient the accuracy of

his diagnosis, it is equally his duty, both to the patient and to himself, to sift each case to the bottom, and to make his own independent conclusions. Thus, in a case of toxic arthritis, failure to discover the infecting focus, while relying on mineral water to remove the symptoms, may be not only disastrous to the patient, but bring discredit on the spa treatment as such and even reflect on the acumen of the doctor who sent the patient. The spa physician must possess not only diagnostic ability, but a fund of patience in dealing with chronic cases beyond the average of men. By his own faith and optimism, often under most discouraging conditions, he must cheer his patients up the toilsome path of recovery.

CHAPTER XVI

MINERAL-WATER TREATMENT

MINERAL-WATER treatment may be internal, by mouth administration, or external, by various baths and douches ; as a general rule both methods being employed simultaneously. In internal administration we rely on the absorption of the water and its contained salts, and look for a pharmacological action ; in baths we look for no absorption and rely on the physical action of the mineral water. There are, however, some forms of internal administration, e.g. the Plombières douche per rectum, in which mechanical action rather than absorption is aimed at.

The question at once arises as to how much of the result of mineral-water treatment may be attributed to the action of the water, as such, to hydrotherapy, and how much to the mineral water in virtue of its ingredients. Further, what difference, if any, exists between a solution of salts prepared in distilled water by the chemist and a similar solution obtained from a mineral spring.

Until recently the saline, and to some extent the gaseous, contents of mineral waters have alone been considered in comparative analyses, and, unless we are to recant all our belief in the efficacy of drugs, the importance of these ingredients, at any rate in internal administration, is obvious. Recent developments of science, however, have modified profoundly our whole conception of matter, and it is now realized that the whole question of mineral water is much more complex than hitherto assumed, and that certain heretofore unsuspected physical conditions of liquids may prove of importance equal, or more than equal, to the gross chemical ones revealed by ordinary analysis.

It would naturally be supposed, and indeed is very

widely affirmed, that an artificial mixture of salts in water would have the same physical properties, and give the same physiological results, as an apparently identical solution of mineral water. Spa physicians have always denied this proposition, but their denial, unsupported by scientific evidence except that of clinical experience, has naturally been attributed to interested motives or to a prejudice little removed from superstition.

Whatever ground they may have had for this belief, the results of modern research show that there are other factors to be taken into consideration, and tend more and more to confirm those of clinical experience. We are still groping in the twilight of half-accepted theories and half-understood experiments, and the time is not yet ripe for dogmatism. But meantime we may consider some of the possible factors in the problem, in so far as we have yet grasped them.

Before, then, we can answer the two questions propounded at the beginning of this chapter, we must determine what is the action on the body of plain water at various temperatures applied internally and externally, then pass in review these newly discovered physical properties of natural mineral waters, and finally and dispassionately consider whether they do or do not so differentiate a mineral water as to endow it with a power of influencing the organism not possessed by ordinary water.

The Quality of Freshness.—This quality, common to all spring waters and not, of course, confined to mineral water, is very hard to define, and almost equally hard to explain. It is not, of course, a newly discovered property of water, and in certain directions its value has long been recognized. Fortescue Fox¹ has repeatedly drawn attention to its importance in drinking-water, and quotes the observations of Dr. Quiserne, based on the action of the baths of

¹ *Roy. Soc. Med. Balneol. Sec.*, May 15, 1911; and *Medical Hydrology*, 1913.

It is not necessary to have recourse to Armand Gautier's views about the "endogenous" origin and consequent nascent action of some mineral waters, as freshness is a property common to all spring waters and to the sea.

Bagnoles de l'Orne, as to its equal importance in baths. As to myself, a long and peculiarly intimate experience of mineral springs when used in their natural state as baths, and of the same waters conveyed through pipes, has so impressed on me this view of Dr. Quiserne as to change my whole mental attitude in regard to balneology. For I regard the quality of freshness of at least as much importance in baths as in drinking water (cf. p. 83).

As to what constitutes this quality. There can be no doubt that it is to a large extent, and personally I think chiefly, due to the presence of dissolved and free gases, but it may also be due in part to some of the conditions described below, or to some other undiscovered and unstable physical condition.

Gases present in the water, and especially carbonic acid gas, render it more palatable and readily assimilated, and dissolved salts are thereby absorbed more rapidly.

The other possible factors which we have to consider are ionization, osmotic pressure, radio-activity, and the colloidal state.

Ionization.—A salt dissolved in water appears to undergo, apart from its mere solution, more or less profound chemico-physical modifications. A large proportion of its molecules is dissolved as such (electrically neutral molecules), but a certain proportion is split up into smaller electrically charged radicles or ions, which are quite distinct from atoms, and may consist, either of homogeneous atoms or of groups of combined and dissimilar atoms. These ions carry, some a charge of positive electricity—electro-positive ions—others a negative charge—electro-negative ions. Such a solution is a good electrical conductor or electrolyte.

If now a constant current be passed between electrodes through the electrolyte, these ions may be collected, the electro-positive ions seeking the negative electrode or kathode, and hence being known as “kations,” while the electro-negative ions are repelled from the kathode and seek the anode, and are termed “anions.” Metals and the ions

of alkaloids are "kations," acid radicles and the hydroxyl ions of alkalies "anions."

The degree to which this splitting off of ions takes place, or the "degree of dissociation," varies under different circumstances. Up to the point of complete ionization (v. p. 76), the weaker the solution the greater the proportion of free ions, and the ionization of certain mineral waters is believed to be more complete than that of a corresponding artificial solution of salts, and that of weakly mineralized waters than that of stronger waters. The importance of these free ions from a therapeutic standpoint is very great; indeed, to quote Leduc, "the majority of chemical, toxic, and therapeutic actions of electrolytic solutions are ionic in nature . . . and the majority of drugs given by the mouth owe their activity to ions. For example, we prescribe solutions of potassium iodide, which contain electrically neutral molecules KI, electro-positive ions K, electro-negative ions I. It is to these last that all the activity is due, and it is proportional to their concentration."

Solutions capable of conducting electricity are known as electrolytes, and, as we have already seen, solutions containing many free ions are good conductors; indeed, the degree of ionization of a mineral water may be measured, other conditions being equal, by its degree of conductivity (cf. p. 76). *Such solutions are in a state of perpetual dissolution and reconstruction, are in fact "nascent."*

Osmotic Pressure or Tension.—"Dissolved substances behave like gases or vapours, spreading through the solvent with a certain measurable 'osmotic pressure,' which follows the same laws and has the same physical constants as in the case of gases and vapours, being, as in these cases, proportional to the molecular concentration—i.e. to the number of molecules dissolved in a litre of solution.

"The osmotic pressure is measured by cryoscopy, i.e. by the lowering of the freezing-point of the solution in relation to that of pure water, this lowering being proportional to the molecular concentration. In solutions con-

ducting electricity the freezing-point is always lower and the osmotic pressure greater than the molecular concentration would indicate, because of the dissociation of molecules into ions, which from the point of view of the osmotic pressure and freezing-point behave like independent molecules." ¹

Mineral waters may be divided, according to their osmotic pressure,² into a hypertonic group, whose pressure is higher than that of the blood; an isotonic group, whose pressure is about the same as that of the blood; and a hypotonic group, whose pressure is distinctly lower than that of the blood.

Were we dealing with an artificial solution of salts, these terms could be translated more simply into those of specific gravity; but from what has been already said as to the comparative richness in ions of some mineral waters, it will be seen that the osmotic pressure of a mineral water may be higher than that of a corresponding artificial solution of salts.

The question of the osmotic pressure of a mineral water is evidently of some importance when the water is given internally.

Colloidal State.—One possible consequence of the dissociation of mineral waters is the transformation of their metals into the colloidal state, i.e. into a state of ultra-microscopic emulsion. In such fine subdivision their total surface area is immensely increased, and with it their therapeutic potency.

Radio-activity.—The possible influence of radio-activity has been already discussed (p. 90). Apart from direct action in the body, it may act indirectly by maintaining in suspension colloids in ionized water and by resuspending precipitated particles, thereby "stabilizing" the composition of mineral water. In the waters of d'Enghien P. Daniel showed the presence of electro-negative colloids susceptible to radium rays. In a partly precipitated solution they could be resuspended by β rays, so that a mineral water would "*die*" on storage by loss of its radio-activity and by

¹ Leduc, "Ionic Medication," *Med. Ann.*, 1912.

² Vide Appendix, p. 276.

consequent permanent precipitation of its colloids (Arnozan and Lamarque).

Effects of Drinking Plain Water.—Water constitutes of course the preponderating bulk of the living organism, and is the vehicle by which all nutriment is absorbed and all waste products are eliminated.

As the loss of water from the body amounts to about 100 oz. per diem, we must have that intake in some form or another by the mouth to maintain equilibrium. The individual necessities vary of course with individual bulk and other factors, and the tolerance of the body, both in the matter of diminution of water supply and more especially of increase, is very considerable.

Under normal conditions water entering the stomach is rapidly passed on to the duodenum, and is absorbed throughout the whole length of the intestine. The rapid ingestion of too large quantities will naturally tend to proptose the stomach, and thereby delay the passage of the liquid to the duodenum. At the same time it may exercise effects on the body temperature, and, what is more serious, reflex effects on the heart that have been occasionally fatal. It is therefore advisable to administer mineral water in small doses, 4 to 10 oz., and eschew the heroic draughts that once were popular.

Absolutely pure distilled water is an irritant to the stomach on account of its tendency to upset osmotic equilibrium¹ and, theoretically at any rate, a water isotonic with the blood should be least irritant. The physiological effects of drinking plain water will depend upon its temperature and upon the condition of the stomach at the time in regard to presence of food and its stage of digestion.

Cold Drinks.—Cold water acts on the mucous membrane of the stomach much as it does on the skin, and for a full account the reader is referred to the section on cold baths. There is a brief period of shock, followed by reaction and

¹ Cf. *Amer. Journ. Phys. Therap.*, vol. i, No. 5; also O. Liebrich, quoted by Weber, *Climat. and Balneotherapy*.

by certain reflex happenings. These effects achieve their maximum when the contrast of temperature is great, i.e. with very cold water, and, in so far as beneficial reaction is concerned, when the quantity is small. When large quantities of very cold water are taken at one dose the shock is great, the reaction is delayed, the body temperature is lowered, the pulse slowed, and, unless the shock is severe enough to depress the heart, the blood-pressure raised, and inhibitory influence is brought to bear upon glandular activity; with small quantities, a momentary vaso-constriction is followed by the glow of reaction, and a rise of blood-pressure; glandular activity is increased, and also muscular motility—a general tonic effect, in fact. This effect is passed on to the intestine, and bowel action is stimulated.

Warm Drinks.—Drinks about the body temperature, the point of thermal indifference for the stomach, act much as do “indifferent baths” (vide p. 251) on the skin. There is no stimulation, the gastric juice is simply diluted. In large quantities, of course, warm water acts as a foreign body and may cause nausea and vomiting.

Hot Drinks.—Very hot drinks in small quantity are stimulant just as are cold drinks (compare the action of hot baths of brief duration). Larger quantities (again compare hot baths of long duration) raise the body temperature, quicken the pulse, and lower the blood-pressure.

Condition of Stomach.—If the stomach is empty, the water acts as a flush, and is passed on more or less rapidly through the pylorus; if food is in the stomach, a certain amount of dilution of gastric juice occurs, and the passage of the water to the duodenum is somewhat delayed.

Excretory Effects.—All forms of water increase to some extent metabolism and the elimination of waste products. Cold water increases the catabolism of fats, and, as it also stimulates the action of the bowel, is preferable to hot in the treatment of obesity and chronic toxæmias.

The Effects of Drinking Mineral Water.—These will be the effects of drinking plain water, hot or cold, as the

case may be, plus the effect of dissolved salts and gases. The effect of these ingredients may be modified, as we have already seen, by the osmotic tension, ionization, and other qualities of the water.

Baths : Effects of Plain Water on the Skin.—Beyond a certain amount of maceration of the outer layers of the cuticle, water of course is not absorbed by the skin. It is the various thermal and mechanical and, in the case of mineral water, the added chemical and possibly electrical stimuli, acting on the skin, which reflexly influence the whole organism ; and how potent those stimuli, and how far-reaching their reflex effects, is a phenomenon as surprising as it is fascinating to investigate. The potential importance of the skin as a modifier of metabolism is, I think, not fully appreciated, and certainly is not emphasized in the ordinary course of medical instruction.

The Skin as an Organ.—Anyone can see, without further argument, the significance to the whole organism of any modifications of function of a great internal organ like the liver, but one is apt to forget that the skin is not merely a mechanical protective covering of the body, but a true glandular organ, and a huge one.

It is spread out thinly, and so does not fit our mental conception of an organ ; but if we conceive it, with all its multitude of glands, ducts, capillaries, and nerve endings, as rolled or folded up into a compact mass and tucked away inside the body, we see what an important organ it really is. In addition to being a glandular organ, it is a special sense organ, enabling us to communicate with the outside world through the special end organs for touch, pressure, pain, and temperature sensation. How important this function is has been borne in upon us as never before by the multitudinous cases of anæsthesia from gunshot wound of nerve.

Finally it is, apart from these functions, the principal factor in the heat-regulating mechanism of the body.

Being designed essentially to react to external stimuli, instead of its organic potentialities being diminished by

being spread out in a thin layer, these are really increased, and in equal measure are increased our facilities for influencing it directly by therapeutic stimuli.

The dermal structures with which we are most concerned are the sweat glands, the nerve endings, and the capillaries. By influencing one or all of these three we can influence :

- (i) The body temperature and by it general metabolism.
- (ii) The amount of liquid withdrawn from the body by the skin and so the process of osmosis in the body generally, and the amount of work in the matter of excretion of liquid by the kidneys, lungs, and bowel.
- (iii) The excretion of toxic substances by the skin.
- (iv) The blood circulation in the skin, and, both reflexly and mechanically, circulation in internal structures, thereby influencing profoundly both the blood-pressure and metabolism generally.
- (v) The actual constitution of the blood, as will be shown later, not only as regards its plasma density, but as regards the number of erythrocytes and leucocytes and the amount of hæmoglobin, an effect the importance of which on the body generally is obvious.
- (vi) The nerve endings, and reflexly every part of the nervous system, including the sympathetic, and incidentally the metabolism of almost any or every structure as desired.

As already stated, no attempt will be made here to write a formal treatise on balneology, and the above phenomena will be dealt with as briefly as possible, and only discussed in so far as is necessary to give a grasp of the principles involved in the rational practice of hydro-therapeutics.

(i) **The Body Temperature.**—Metabolism is retarded in cooled tissues, and, within certain limits, increased in warm ones. This is more especially the case when the cooling or warming is continuous ; with a rapid alternation of the two, other factors enter, as will be seen when dealing with reaction. Cold applied to the skin does not necessarily reduce the bodily temperature, for moderate cooling of

the surface causes increased bodily heat production, more especially in the muscles, and this heat production takes place principally at the expense of the non-nitrogenous substances.

As moderate heating of the skin acts in the converse manner and stimulates nitrogenous catabolism, we have a definite, if limited, command over both nitrogenous and hydrocarbon and carbohydrate metabolism.

The stimulating effect on heat production of cold applied to the skin is a point of practical importance in the treatment of hyperpyrexia. The cooling effect of mere cold sponging in fever is greatly nullified by increased heat production and by the defensive mechanism of the dermal vessels, which contract, and so diminish the amount of blood exposed to cooling. By the employment of alternate sponging and skin friction the latter impediment is removed. The skin is made rosy, more blood is brought to the surface, the veins are emptied, and, as the circulation is made more brisk, more blood is cooled.

Practically we can cool or heat the tissues beyond the skin-layer, either locally, as by a douche or local vapour or hot-air bath, or generally, in a complete-immersion bath of water, vapour, or air; or we can warm them still more deeply by the more penetrating radiant-heat rays, or by certain electrical currents (diathermy).

It is so well recognized that the heat-regulating mechanism of the body does not fail us under ordinary circumstances that we at once look for trouble if we find the body temperature raised even one degree beyond the diurnal variation. Immersed in water the case is quite different; partly from the conducting power of water and partly from the putting out of action of the chief defences of the heat-regulating mechanism, a condition of artificial fever is brought about after a very few minutes of immersion to the neck in a hot bath.

With a cold bath, reduction of the body temperature is a much less rapid process. The stimulus of cold induces

increased heat production, and the skin anæmia reduces the loss of heat by conduction from the skin. The degree of fever caused by immersion in a hot bath depends not only on the temperature of the bath and the length of the immersion, but varies considerably with the individual. For instance, I took the mouth temperature of twenty chronic arthritic patients before and during a bath. The patients were immersed in the same large bath (Public Priest) up to the neck, the temperature of the bath being maintained throughout at its usual level of 104° F. Before the bath the records were all from 98° to 98.8° F. After ten minutes' immersion, the lowest temperature recorded was 99° F., the highest (in two cases) 101.6° F. I could discover no particular reason at the time to account for one man having a temperature nearly 3° higher than another, though now, on looking back, it has occurred to me that it might be due to "intensive action" on local pathological material.¹ One sees so frequently during the progress of a course of hot baths, and especially in the early stages of the course, an exacerbation of local symptoms in arthritic cases, due to this intensive action, that one comes to regard this phase as normal. Indeed, it is a maxim amongst patients at a spa that "you must get worse before you get better." In a subsequent experiment similar results were obtained, but the highest pyrexia, again 101.6° F., occurred in a man whose temperature before the bath was already somewhat raised, 99.6° F.

Leonard Hill and Martin Flack,² experimenting on themselves and on students with immersion baths at 105° to 110° F., found the body temperature after twenty minutes' immersion to be raised to 102° to 104° F. As a result, in addition to the changes noted here of cutaneous hyperæmia, lowered blood-pressure, and rapid pulse, they found that a condition of hyperpnœa ensued, and as a consequence the partial pressure of carbonic acid in the alveolar air was lowered

¹ Cf. Fortescue Fox, *Medical Hydrology*.

² *Proc. Physiol. Soc.*

from the normal 5 or 6 per cent. to 3 or 4 per cent., so that the body was not only cleansed of carbonic acid, but well oxygenated. An artificial increase of the body temperature causes loss of weight. Part of this loss may be due to profuse sweating, but part is due, as we have already noted, to increased nitrogenous catabolism.

It is evident, then, that a raised bodily temperature,¹ such as we may get after immersion in a hot bath, is responsible for profound alterations of metabolism.

Another effect of artificial pyrexia is that the defensive mechanism of the body against microbic and toxic infection is also strengthened. Thus Rolly and Meltzer² found that phagocytic activity reached its maximum at about 104° F., declining again as the temperature rose to 106·7° F. Also, in rabbits kept for periods of from four to twenty days in a state of artificial pyrexia, the production of anti-toxins and agglutinins was accelerated, while the animals remained well and healthy, and no signs were found of the visceral parenchymatous changes so common in ordinary pyrexia.

It has been suggested that the natural febrile reaction consequent on microbic infection is part of the defensive mechanism of the body, the high temperature having an inhibiting effect on the growth of some organisms. This theory was based chiefly on the experiments of Pipping on the effect of fever-level temperatures on the growth of pneumococci in broth. Rolly and Meltzer, however, pointed out how altered were the conditions when the organisms actually infected the body, and it would rather seem that a moderate general pyrexia, such, for instance, as results from a hot bath, is only indirectly bactericidal by means of its already noted stimulant action on the defensive mechanism of the body.

The possibility of another and more direct result of the

¹ Practically we can increase bodily heat loss 70 per cent. or decrease it 90 per cent. by baths. Water containing weak chemical irritants, e.g. Priest Bath, facilitates heat loss if applied below the body temperature.

² *Proc. Physiol. Soc.*, vide *B.M.J.*, May 22, 1909.

artificial heating of the tissues has, however, to be considered. In the case of the extreme localized hyperpyrexia induced by a local hot-air bath, e.g. to the knee at 400° to 500° F., or by a local vapour bath at 120° to 130° F., or by diathermy, we may very conceivably get temperatures that would materially affect local bacterial growth in those cases, e.g. some gonorrhœal ones, in which there is actual joint invasion.

I am not aware of any reliable records of the temperature of the interior of living tissues under such conditions, but it is probable that it must be raised considerably, and it may possibly be so far raised as to be germicidal, either directly, or, indirectly, by so modifying the culture medium of the patient's tissues as to make it inimical to the growth of micro-organisms.

Thus the gonococcus is killed in cultures by an exposure of ten minutes to a temperature of 111° F., or immediately by a temperature of 113° F., though there is reason to believe that somewhat higher temperatures can be withstood by the coccus within the tissues than when outside the body.

(ii) **Withdrawal of Liquid from the Body.**—Liquid is removed from the body chiefly by means of the kidneys, the bowels, the skin, and the respiratory organs; and by influencing the skin by means of hot or cold baths we can modify materially the relative proportion excreted by these various channels. The total amount of liquid lost varies considerably with the individual, and in the same individual the relative proportion passed by each channel varies largely with the temperature of his skin environment. Thus, by varying this temperature by means of baths, we can throw proportionately more work on the sweat glands or the kidneys, and, as we shall see later, the liquid loss from both lungs and bowel can also be influenced by the same methods.

As a general rule, however, our object is to throw more work on to the skin and relieve the work of the kidneys.

The promotion of free sweating is one of the most ancient and universal aims of hydro-therapeutics. Of extreme value,

it assumes perhaps an exaggerated importance in the public mind by its very simplicity and apparent directness of method, where much of treatment is intangible and indirect.

A cold bath inhibits the action of the sweat glands and increases the liquid excretion by the three other channels. A hot-water bath or hot-air bath stimulates the sweat glands as part of the defensive armour of the heat-regulating mechanism, though in the former case almost uselessly. In addition, a bath containing irritating ingredients, such as the sulphuric-acid baths of Rotorua, by causing active hyperæmia of the skin, stimulates the glands yet more, so that a much more copious secretion of sweat takes place after a bath of hot "Priest" water than after one of plain hot water. The sweating, of course, begins in the bath, and is encouraged, if necessary, by a hot-pack afterwards. Still more copious sweating ensues after a vapour bath, and reaches its acme, as might be expected, after a bath in which the steam is mingled with hot sulphurous acid fumes, as in the sulphur-vapour bath at Rotorua.

With hot-air baths we get the same results, which again appear to be increased when the stimulus of certain light rays is added, as in the electric-light bath.

(iii) **Excretion of Toxic Substances by the Skin.**—The skin is a vicarious kidney. The sweat, in addition to water and certain salts, contains fatty acids, carbonic acid gas, glycogen, and certain obscure toxins and micro-organisms, and may also contain appreciable and even large amounts of purin bodies, including uric acid.

Thus, hyperidrosis may not only relieve the work of the kidneys, but may even serve to excrete substances that otherwise would be locked up permanently in the system.¹

On the other hand, Beneke has shown that excessive sweating, without a corresponding intake of water, may so concentrate the urine that on the whole a diminution of

¹ Gout is a disease characterized by retention rather than by over-production of uric acid.

the total excretion of nitrogenous substances results, an observation that shows the necessity of drinking the waters when taking a course of thermal baths.

(iv) **The Blood Circulation of the Skin, and of Internal Structures.**—A short application of either heat or cold acts on the skin as a stimulus and causes temporary cutaneous anæmia, from vaso-constriction of arterioles principally, but also from increased tone of the intervascular¹ tissues, and from contraction of the endothelial lining cells of capillaries. This stage is succeeded by one of reaction and consequent hyperæmia. The primary stage is proportionate directly to the contrast of temperature between the skin and the medium, and, within certain severe limits, to the duration of the stimulus. Thus, the maximum beneficial effect will be obtained with a brief, very hot, or very cold application.

Further consideration of this subject will be given under the heading of cold and hot baths: suffice it here that, generally speaking, the amount of blood circulating in deep structures will be in inverse ratio to that circulating in the skin.

(v) **Changes in Blood-content.**—Stimulation of the skin of sufficient intensity to cause *active* dermal hyperæmia (cf. p. 250) will cause an alteration in the blood-count, and this alteration may be not only local in the area stimulated, but general and in distant parts that have not been stimulated directly. These phenomena were first described by Winternitz² as a result of the study of the effects of cold baths, and his observations were confirmed by a multitude of observers.³ Bearing in mind that a brief

¹ The diagonally arranged involuntary muscle bundles and yellow elastic fibres of the true skin.

² Winternitz, *Blatter für klinische Hydrotherapie*, 1893; also his article in Cohen's *System of Physiologic Therapeutics*.

³ Rovighi, Internat. Congress, Rome (quoted by Baruch); Strasser, *Blatter für klinische Hydrotherapie*, 1893; Magranti, *Giornale della Reale Acad.*, October 1895. For a full discussion of the subject see Baruch, *Hydrotherapy*.

very hot bath has much the same effect on the circulation as a brief cold one, it might be anticipated that similar alterations would be found in the blood-count, and this was found to be the case by Knoepfelmacher.¹ On the same line of reasoning, finding that the reactive phase of a hot acid sulphur bath was not only very pronounced, but very prolonged, I examined the blood-content in bathers taking the Priest Bath, and found, even after comparatively long immersions, the same alterations of blood-count as occur after a cold bath (cf. p. 79).

After a cold bath, and more especially when skin reaction is encouraged by stimulating measures such as friction, douches, and vigorous muscular exercise, a blood-count will show a decided increase of both red and white corpuscles in the cutaneous blood, the increase lasting about two hours. The increase will be found whether the blood be taken from a part that has been immersed, say the finger, or from a part purposely untouched, say the ear. On the other hand, after a hot bath of moderately prolonged duration, there is a distinct decrease of both red and white corpuscles.

It is obvious that such a sudden increase of corpuscles—the results may be seen within ten minutes—could not be due to a fresh formation of cells. The suggestion has been made that these results may be due to the contraction of the surrounding tissues forcing the blood-plasma out of the capillaries, and leaving some of the corpuscles stranded. This, however, would not explain the alteration in distant parts, and Winternitz explained the phenomenon as being due to corpuscles swept out of internal organs, where the blood was in a condition of comparative stasis, into the brisked general circulation. This view was confirmed by a negative experiment of Breitenstein's, who showed that when a rabbit was exposed to heat there was the same diminution of corpuscles in the cutaneous blood as is seen after a warm bath in man, with a simultaneous increase of corpuscles in the liver blood.

¹ Knoepfelmacher, *Wiener klinische Rundschau*, 1894.

(vi) **General Metabolism.**—From the preceding paragraphs it is obvious that, by means of the skin, we can influence general metabolism. We can increase the intake of oxygen and the output of carbonic acid, we can control, to a limited but definite degree, the catabolism of both nitrogenous and non-nitrogenous components of the organism and assist excretion of waste products, and we can even to a very definite extent affect the composition of the blood.

Correlated Areas.—Moreover, in addition to our power of affecting the metabolism of the body as a whole by means of baths, we can, by local applications, for instance, douches, and especially by such potent stimuli as the alternate use of hot and cold water in the Scotch douche, exercise a *selective measure*, and so to a greater or less degree affect the metabolism of almost any desired part of the body, whether that part be a joint or an organ deep-seated in the trunk.

Certain skin areas have been determined which are correlated reflexly with internal organs, and stimulation of these areas will affect reflexly the corresponding organs by altering their blood-supply for the time being. Thus, stimulation applied to the lower dorsal spinal area will influence both the circulation and the motility of the stomach ; over the nates, the pelvic viscera ; over Scarpa's triangle, the genital organs.

We owe much of our knowledge of the nervous correlation of the viscera with certain definite skin areas to the researches of Head.¹ The posterior spinal roots contain sensory fibres for both the skin and the viscera. If a spinal segment supplies sensory fibres to a viscus and also to a certain skin area, that area becomes hyper-algæsic in disease of the viscus. It also exhibits increased excitability to heat and cold, and the reflexes excited by its stimulation are exaggerated, so that we may reasonably suppose

¹ Head, *Brain*, vols. xvi, xvii, and xix ; see also Mackenzie, *Med. Chron.*, August 1892, and Ross, *Brain*, January 1888.

that we have more power by reflex stimulation therapeutically to influence a diseased than a healthy organ. This observation is probably the explanation of the "intensive action" of baths in dispersing unhealthy deposits insisted on by Fortescue Fox,¹ by which is meant that the increased nitrogenous catabolism induced by hot baths affects pathological more than normal tissues.

Again, pain originating in the viscus may be referred to the corresponding skin area, so that, conversely, a soothing of the pain in the skin area, either by counter-irritants or by such means as warm fomentations or massage, may relieve a deep-seated pain. The explanation of the referred skin pain may be either an overflow of the irritation from the visceral fibres through the spinal root to the skin fibres radiating from the same root, or to a confusion of the sense of localization in the higher centres. Thus it is supposed that each peripheral area is represented in the brain; that the brain receives frequent sensations from the skin area as against infrequent sensations from the viscus; and that, consequently, all sensations coming to this particular cerebral centre are apt to be associated rather with the skin than the viscus (cf. Stewart, *Physiology*).

In regard to the metabolism of joints, nerves, and muscles, the same truth was long ago adumbrated by Hilton in his famous aphorism that "the same trunks of nerves whose branches supply the groups of muscles moving a joint furnish also a distribution of nerves to the skin over the insertions of the same muscles; and . . . the interior of the joint receives its nerves from the same source."

We have now seen how, by stimulation of the skin, we can affect the metabolism either of the body generally or of some selected portion locally, and in the light of this knowledge can consider the physiological effects of a cold bath and of a hot bath, and finally, taking into account the superadded factors of mineral water, such as saline

¹ Fortescue Fox, *Medical Hydrology*, 1913.

contents, ionization, etc., we can see how mineral-water baths may have a specific action of their own.

Effects of a Bath of Plain Water.—The effects of a bath are due to (1) the medium; (2) the temperature of the medium; (3) the physical pressure.

1. *The Medium.*—The essential characteristics of water applied as a bath are (a) it is a good conductor of heat; (b) it is a bland, non-irritating medium which supports the body comfortably; (c) it mechanically disturbs the body heat-regulating mechanism.

(a) The rapid conduction of heat from the skin to the water or from the water to the skin enables all the phenomena considered below under the head of temperature to be brought about quickly and effectually.

(b) When used within moderate ranges of temperature near the indifferent point (*vide infra*), by preventing the access of the numerous tactile stimuli subconsciously felt under normal conditions of clothed life, water is a sedative, and as such has obvious valuable uses. Again, by supporting the limbs it mechanically eases painful joints, or by supporting the body enables voluntary use to be made of paresed limbs, which otherwise would be impossible.

(c) By preventing evaporation from the skin, a water bath upsets the automatic heat-regulating mechanism of the body. Except in conditions of collapse or hyperpyrexia, where this attribute may be employed purposely, this is generally a disadvantage, and a danger to be guarded against when giving baths therapeutically.

2. *The Temperature.*—This, of course, is the all-important factor. The skin stimulus of a bath is the contrast between the temperature of the water and that of the *skin* of the bather rather than that of his body temperature, and baths are classified therefore in relation to the skin temperature, a very movable figure, as hot, warm, tepid, cold. The temperature of the covered skin averages about 88° F., but that of the uncovered parts is much less. The air im-

prisoned between the clothing and the skin averages about 86° F., and the body exposed to air at this temperature neither loses nor gains heat from its environment. Still air at this temperature feels to the skin of a resting individual neither hot nor cold, and this point of thermal indifference for air is variably placed at from 85° F. to 90° F.

Water conducting more freely than air, its indifferent temperature point is somewhat higher, 93° F. or 94° F. Baths may be classified, then, as tepid, or subthermal, at or near the indifferent temperature; cold below that range; and hot above it.

Cold Bath.—The first effect of a cold bath is a brisk stimulus or shock to the sensory end-organs in the skin, conveyed thence to the central nervous system, and followed by a response which is carried largely by the sympathetic nerves. This first stage is marked more especially by vaso-motor action in the skin, with all the secondary phenomena which are necessary corollaries of that action. Thus, with the vessels of the skin contracted, there is internal hyperæmia, though not sufficient to prevent a rise of blood-pressure.

This stage is followed by the all-important one of *reaction*, and it is on this stage that the benefits of a cold bath depend. The vaso-motor impulse passes off, the cutaneous vessels dilate, the skin becomes pink, the temporarily quickened pulse becomes slowed and strengthened, so that the blood-pressure remains raised, the muscle tone is improved, and there is a general sense of *bien être*. This sensation is largely due to the improved circulation, not only in the periphery but in the central nervous system, but may in part be due to direct stimulation of that central system. It is in this stage that we begin to find manifested those changes in the blood-content already noted. These two stages represent the phase of stimulation of the heat-regulating centre.

Should the bath be prolonged beyond a certain period, which varies both with the health and age of the individual

and the temperature of the water, the third stage, that of *depression*, ensues. In this stage the heat-regulating mechanism is fatigued and begins to fail, and heat loss begins to exceed heat production. It passes insensibly into the fourth, or *algid* stage, in which, that mechanism having entirely broken down, the body rapidly approaches the temperature of the surrounding medium, and ends in collapse and death.

It is our object, then, in all cold applications to ensure the second stage and to prevent the development of the third.

Hot Bath.—In a hot bath there are the same stages as in the cold bath, but they are less sharply defined and tend to merge more insensibly into one another. All equally depend on a stimulus to the heat-regulating centre, though, in the case of the hot bath, the response is in the direction of diminished instead of increased heat production, and the organism makes unsuccessful efforts to encourage heat loss instead of, as in the case of cold baths, successful efforts to diminish it.

The first stage of vaso-constriction and tonicity is rapidly succeeded by the second of vaso-relaxation, and whereas the second stage of a cold bath is a generally tonic condition, that of the hot bath is one of relaxation and debility. In the hot bath we endeavour to arrest treatment at the first stage if we desire tonic effects, and in the second stage if we wish to relieve pain and stiffness. As we have seen (p. 82), it is the faculty of prolonging the tonic effects of the first stage well into the second which constitutes the especial merit of the hot acid waters of Rotorua.

The Reaction of Active Hyperæmia.—In the second stage of a hot bath the skin is hyperæmic, the veins are full, and the parts relaxed; the appearance, however, is quite different from the pink glow seen in the second stage of a cold bath. We have seen, too, that the blood-content is also quite different in the two conditions. The one might be described as a mild poultice effect, the other

as a mild mustard-plaster effect ; the former is a condition of passive hyperæmia due to withdrawal of vaso-motor influence, the other has been described as one of *active* hyperæmia, and is not easily explained.

There has been a good deal of scepticism about the possibility of an *active* hyperæmia. It is pointed out that arteries dilate as an atonic measure from relaxation of vaso-motor influence ; how is it possible for such a relaxation to be compatible with a tonic hyperæmia of the skin ?

There are several possible factors. In the first place, stimulation of the longitudinal¹ muscular fibres of the arteries would dilate the vessels actively, while contraction of the circular fibres would narrow their lumen. As longitudinal fibres are found in the larger vessels only, both in arteries and veins, this is probably a minor factor. More important is the action of the capillaries. These have no muscular coat, and their alteration in lumen is effected by the amoeboid-like movements of their endothelial lining cells. They are, however, supported and enmeshed by a close network of unstriated muscle and yellow elastic tissue fibres, supplying the function of an elastic and muscular coat. These muscular fibres, as is muscle elsewhere, are not in a state of placid continuous rest broken by brief periods of active contraction, but are in a state of rhythmic rest, or, if it be preferred, of rhythmic contraction.

Skin-heart Function.—In this way they cause a slow pulsation of the blood in the capillaries, not synchronous with that of the heart, and aid the circulation. They act in fact much as the multiple hearts of the frog, and the phenomenon was termed by Woods Hutchinson² the “ skin heart.”

This rhythmic contraction of the capillaries is readily seen in the invertebrates, but may also be observed in the

¹ Exner, *Acad. of Sciences*, Vienna, 1877, pointed out the possibility of this by showing how the lumen of a stretched rubber tube was increased when its ends were approximated.

² *Boston Med. and Surg. Journ.*, November 1897.

web of the frog's foot, and, in the mammalia, in the bat's wing and rabbit's ear. Remembering that in man some 10,000 square feet of cutaneous capillaries, with a capacity of 30 per cent. of the body blood, are involved, it is easy to see how powerful is the influence of this quasi-reptilian skin heart.

Cold water applied to the skin stimulates the contraction of the skin muscles through their intrinsic ganglia, powerfully emptying the capillaries by compression—the first stage of the cold bath. Then follows a relaxation of the muscles, the capillaries are dilated and fill with arterial blood. The limited application of cold is, however, a powerful stimulus to muscle, and the “skin heart” beats again with renewed vigour. At the same time the central heart has also been stimulated by the cold bath, and the blood-pressure rises and enhances the effect of the peripheral hearts.

One other factor is also at work. Bier¹ maintained, and his experiments were confirmed by those of Ritter, that tissues made anæmic by constriction, when the constriction was removed and the blood allowed access again, exercised a selective action, so that arterial blood alone filled the area affected and venous blood was excluded.

In the case of our cutaneous capillaries they have been powerfully squeezed, emptied, and refilled. The inference is that selective action would be exhibited.

The case of deep massage is closely analogous, and it may well be that some of the muscle-generative power both of massage and of voluntary muscular contraction may be due to this cause.

An active hyperæmia, then, is a more rapid circulation of arterial blood through rhythmically pulsating capillaries.

The Tepid Bath at the Indifferent Temperature.—Finally, there is the bath at the “indifferent temperature,” in which there is no appreciable contrast between the temperature of the skin of the bather and that of the bath, in which there

¹ For a full discussion of the subject of active hyperæmia see Baruch, *Hydrotherapy*.

is no call on the heat-regulating centre, and consequently neither stimulation nor depression. The absence of stimulation all would admit, the absence of depression on long immersion is not so generally recognized, yet in some of the Swiss resorts patients remain for many hours in the water without serious depression, and thirty years ago I remember in Guy's Hospital seeing a patient kept continuously in a bath for several days and nights on account of unmanageable bed-sores, consequent on pyæmia, and to his manifest comfort.

The bland medium, which evenly supports the body, acts as a protective envelope, and shuts off the numberless tactile sensations which normally, though subconsciously, affect the central nervous system. Such a bath is therefore a sedative, comparable to a quiet sick chamber, and as such has its obvious uses.

The following summary shows in tabular form the main physiological effects of hot and cold baths:

| COLD BATH | HOT BATH |
|--|--|
| <i>First Stage—Prolonged</i> | <i>First Stage—Brief</i> |
| 1. Preliminary shock great. | 1. Preliminary shock moderate except with very high temperature. |
| 2. Skin anemia from vaso-constriction of surface vessels. | 2. Vaso-constrictive skin anæmia brief. |
| 3. Action of sweat and sebaceous glands checked. | 3. (?) Inhibition of sweat- and sebaceous-gland action brief only. |
| 4. Arterial blood-pressure increased. | 4. Arterial blood-pressure increased. |
| 5. Pulse accelerated. | 5. Pulse accelerated. |
| 6. Respiration deepened and accelerated. | 6. Respiration accelerated. |
| 7. Heat production increased. | 7. Heat production diminished. |
| 8. Muscle tone increased. | 8. Muscle tone increased. |
| 9. Involuntary muscular contractions—shivering. | 9. No shivering. |
| 10. Pain and stiffness in general increased; causalgia generally diminished. | 10. Pain and stiffness relieved, but causalgia generally increased. This feature becomes more marked as the first is merged in the second stage. |

Second Stage—important and prolonged: Stage of Reaction, or of Active Hyperæmia.

1. Vaso-constriction removed, active hyperæmia of skin (mustard-plaster effect).
2. Sweat and sebaceous glands inactive.
3. Pulse slowed and strengthened.
4. Arterial pressure raised.
5. Heat production increased very greatly.
6. Shivering passes off; sensation of warmth in the skin.
7. Increased catabolism of fats more especially.
8. ¹ Increased quantity of urine, and somewhat of urea.
9. Increased depth of respiration.
10. Increased intake of oxygen and output of carbonic acid.
11. Body temperature constant.
12. Red and white blood corpuscles in dermal circulation increased in number.
13. Muscle tone increased.
14. General tonic effect on all parts of body, including nervous system.

Third Stage—Fatigue of Nerve Centres

1. Skin anæmic.
2. Increased metabolism of both proteins and fats.
3. Blood-pressure falls slowly.
4. Body temperature falls slowly.
5. Muscular relaxation slowly develops.

Second Stage—important and prolonged: Stage of Reaction or Passive Hyperæmia.

1. Vaso-constriction removed, passive hyperæmia of skin (poultice effect), very doubtful transitory active hyperæmia.
2. Sweat and sebaceous glands active.
3. Pulse more rapid.
4. Arterial pressure falling, except possibly in very hot baths.
5. Heat production diminished.
6. Skin is actually warmed.
7. Increased catabolism of both fats and nitrogenous tissues.
8. ¹ Urea output increased, urine rather diminished.
9. Increased rapidity of respiration.
10. Increased intake of oxygen and output of carbonic acid.
11. Body temperature rises.
12. Red and white corpuscles in dermal circulation diminished in number.
13. Muscle tone diminished.
14. Languor, debility, and loss of tone.

Third Stage—Fatigue of Nerve Centres

1. Skin congested.
2. Very great increase in metabolism of proteins and fats.
3. Blood-pressure falls rapidly.
4. Body temperature rises rapidly.
5. Muscular relaxation, including heart muscle, rapidly develops.

¹ Not confined to one stage, but placed here for convenience.

Fourth Stage

1. Vaso motor paralysis, venous and capillary stasis.
2. Rapid fall of body temperature.
3. Rapid fall of blood-pressure.
4. Collapse.

Fourth Stage

1. Vaso-motor paralysis, venous and capillary stasis.
2. Rapid rise of body temperature.
3. Rapid fall of blood-pressure.
4. Muscular, including heart, paralysis.

3. *The Physical Pressure.*—In a bath of four feet or more in depth, there is very definite direct pressure on the capillary and venous circulation of the lower extremities. Of more practical importance is precordial pressure, though this is of only a few inches of water. Many patients have alarming palpitation if the water of a hot bath rises above the nipple line, though this is probably rather a reflex phenomenon than one due directly to pressure.

In the various douches, including the underwater douche, use is made of local direct pressure effects as well as of reflex thermal stimulation.

Mineral-water Baths.—We have now considered, in fairly full detail, the physiological effects on the organism of baths of hot and of cold plain water. A mineral-water bath will of course have these same effects plus any additional effects that may be caused by its specific qualities. As we have already seen, the known possible added factors are, in addition to or comprised in the quality of freshness, which may or may not be present, ionization, osmotic tension, radio-activity, and the presence of gases, salts, or acids.

As to what, if any, may be the action of the first three factors we are yet imperfectly informed and the whole matter is still *sub judice*, but in regard to gases, salts, and acids there can be no question whatever of their potent action on the skin.

Gases.—Many gases are contained in mineral waters, either dissolved or free, but the most important are carbonic acid, sulphuretted hydrogen, and perhaps sulphurous acid.

Carbonic acid gas is particularly common in mineral waters, as it may be found both in volcanic and non-volcanic springs, and is more especially abundant in the calcareous springs of limestone regions. It is not absorbed by the vessels of the skin, but acts as a direct stimulant to unstriated muscle, and so to the peripheral circulation by promoting "active" hyperæmia. This "skin-heart" function is used therapeutically to lessen the work of the central heart and is the *raison d'être* of the Nauheim baths. In addition, the indifferent temperature point of carbonic acid being only 75° , a comparatively cool effervescing bath feels warm (cf. Old Priest Bath, Rotorua, p. 77). As most springs containing much carbonic acid are comparatively cool, this is an important practical point.

Sulphuretted hydrogen is important, not so much for its physical effect, for it is less stimulating to the skin than carbonic acid, as because it is probably to some extent absorbed. On the whole, it is rather disadvantageous in a bath in any quantity, as it is also necessarily inhaled.

Sulphurous acid is stimulating to the skin in the same way as carbonic acid, but it too is liable to be inhaled. It is the presence of these two sulphurous gases in the waters of Rotorua which constitutes the chief drawback of the natural baths, and makes them impossible for some patients.

Salts.—No one can doubt the greater stimulating property of, say, sea-water as compared with fresh water, and indeed the sea constitutes the greatest body of mineral water in the world, and is the prototype of all saline springs. Salt tends to promote the reaction of stage two of a bath (cf. p. 253), and most definitely to prolong it.

Most of the salts of mineral waters have more or less of this same action on the skin, but of course, in the weak hypotonic waters, the action is very slight.

Acids.—These, while uncommon ingredients of mineral waters generally, are very important factors in the Rotorua

waters. Their stimulating action on the skin circulation is very pronounced indeed, much more so than that of salt. They, like salt, favour the reaction of stage two (cf. p. 253), and, even more than salt, they prolong it. The changes in the blood-content thereby induced are dealt with on page 79 under the head of Priest Waters.

CHAPTER XVII

ACCESSORY PHYSICAL TREATMENT

UNDER this heading come massage, electrical treatment, and remedial exercises, and both our appreciation of the benefits of these methods and our skill in their utilization have increased enormously during the last few years. In the early stages of the war multitudes of wounded men quitted the surgical hospitals, their actual wounds healed, and the primary ravages of shot and shell repaired, as far as surgical aid could repair them. Officially they were "convalescent," but their condition was often pitiable and their disabilities apparently hopeless. To meet this emergency all the resources of physical treatment were called into play. The existing centres of treatment, and amongst them Rotorua, rose to the occasion, and results that appeared at that time almost miraculous were obtained. Soon on every side, in every country, fresh hospitals for physical treatment sprang up, fresh staffs of masseurs were trained, and by the end of the war not only had physio-therapeutics received full recognition, but it was in danger of suffering from over-popularity.

As a result of the immense impetus thus given to physical treatment, the whole subject is on a different plane from that existing in 1914. There are infinitely more medical men with a practical knowledge of the subject, there are whole hosts of trained masseurs, masseuses, and electricians, and, in addition, our methods of application of treatment have been improved. The results of this enormous gain of experience remain to benefit not

only the wounded in war, but the even greater array of the wounded in the battle of life.

Massage.—This constitutes one of the most important—perhaps *the* most important—of forms of accessory treatment. In the Government spas true massage is given by prescription, and under medical direction only, thus eliminating that element of quackery that has for so many years been the bane of massage.

This is no place for a description of the technique of massage, for which the reader is referred to one of the many textbooks on the subject, but the following paragraphs, condensed from the admirable account of Kellogg, give a brief summary of its physiological action and effects.

The effects of massage are *mechanical*, as when the hand of the operator promotes the movements of blood and lymph; *reflex*, in which distant effects are set up by stimulation of the cerebro-spinal or sympathetic nerve-endings; and *metabolic*, really a corollary of the other two.

Effects on the Nervous System.—Stimulant or sedative effects may be obtained as desired by varying the forms of manipulation.

Effects on the Muscular System.—Massage greatly increases the blood-supply of a muscle,¹ thereby affecting its nutrition, and indirectly affecting the general circulation. Metabolism and heat production are greatly stimulated.

Effects on the Bones and Joints.—Increased blood-supply to a muscle increases the supply to a bone immediately underlying it, favourably influencing its nutrition, together with that of the cartilages, ligaments, and other joint structures. At the same time there is increased circulation through the red marrow, the importance of which to the blood is obvious.

Effects on the Circulation.—The current through veins and lymphatics is hastened, with obvious direct effects

¹ As already pointed out, the "selective action" for arterial blood described by Bier may probably be a factor.

on the local metabolism and with secondary effects on the general circulation and heart's action, and indeed on the body generally.¹

Exactly the same effects of hæmatogenesis are seen as after cold baths, a temporary increase of the red-cell count being noted. Phagocytosis is also increased.

Effects on Respiration.—Depth of respiratory motions² and of CO₂ excretion are increased.

Effects on Heat Functions.—Deep massage, by its effect on the muscles, increases heat production; superficial massage, by increasing skin hyperæmia, increases heat loss.

Electrical Treatment.—Electricity has been used, in conjunction with other physio-therapeutic measures, at almost all spas for very many years; but since the war showed its efficacy in the treatment of wounded it has made enormous strides, and, instead of being the speciality of a few practitioners, its employment has been widespread and almost universal. It is viewed from two different standpoints. Most of us who before the war had been accustomed to employ it widely believed that it had a very definite recuperative action on nervous tissue, and hence it was used in neuritis, and, in the form of the Schnée and other electric baths, was designed simply to pass a current from one part of the body to another without any ulterior motive of causing muscular contractions; those whose experience has been gained mainly in the treatment of muscular paralysis resulting from gunshot wound have had their attention focused on muscular contraction, and are inclined to doubt the efficacy of electricity in other directions. With a pretty large experience of both civilian and war work, I am inclined to think that our attitude in

¹ Increased muscular metabolism, whether as a result of muscular exercise or excited passively by massage, leads to the increased formation of CO₂ in the muscular tissue, and this, reaching the respiratory centre, acts as a "hormone," and excites the centre to greater activity.

² Cf. footnote 1.

times past was more optimistic than the facts warranted, and, on the other hand, the war-workers' view is possibly too narrow. Possibly the truth will be found to lie between the two extremes, and that electrical impulses passing down a nerve that is *no longer inflamed* do tend to keep open paths of nervous impulse. Certainly, however, they are better omitted until all inflammation has subsided.

Certain it is that at spas an enormous amount of useless electrical treatment is given, especially on the prescription of masseurs and "medical electricians," and the lay prescription of massage and electricity is a scandal of the first magnitude. In the government-controlled spas of New Zealand, and more especially at Rotorua, such treatment is given on medical prescription only, and practitioners sending their patients to Rotorua may rest assured that they will not be able to procure electrical treatment at the baths without a prescription, though of course they may get it outside.

The equipment at Rotorua is really very complete, and is always being added to, so that there are few treatments indeed which cannot be obtained.

All, or nearly all, electrical treatments are enhanced in effect by the fact that the patient is also taking baths, as the skin is generally softer, moister, and better supplied with blood, and its resistance is thereby diminished. Also the bath treatment and the electrical treatment are, to a large extent, complementary, and finally—and this is by no means the least important factor—a patient taking a course of spa treatment will also readily take his electrical treatments with unfailing regularity, instead of at irregular and uncertain intervals as he is apt to do at home.

Electrical treatment may be given in the usual way with moistened electrodes; or it may be used to enhance the effects of massage by making the masseur's hand the electrode as in electro-massage; it may be given in a full bath, where the patient's body is exposed to the largest possible electrode, the surrounding water; in the *Schnée*

multipolar bath, where selected extremities are immersed in independent baths, so that the current path can be directed at will; it can be used for ionic medication, the introduction of drugs through the unbroken skin; or, in the form of the static current, high frequency, or X-ray.

Again, electricity can be used as a vehicle for heat or light in the form of diathermy, hot-air baths, and electric-light baths.

For the actual technique of treatment the reader is referred to a work on medical electricity, but it may be helpful to give a list of the usual conditions treated with electricity at a spa, and for convenience it is assumed here that the spa is Rotorua, as it alone in New Zealand is at the time of writing fully equipped.

Neuritis.—As it is usually a mixed nerve that is affected, we have to consider both the sensory and motor sides.

Sensory.—The relief of pain and the recovery of normal sensation are our primary objects, and it is on this particular subject that there is room for difference of opinion as to the efficacy of electricity. First of all, having sought and removed any probable cause such as a focus of infection, prolonged rest of the part either by sling, splint, or bed, is essential, and if possible subthermal baths are given. The constant current with the anode to the nerve is used to soothe pain, followed by the lightest possible effleurage. Later, a fine faradic current or sinusoidal current, either by electrodes or in the full electric bath or Schnée bath. If these measures fail, the ionic introduction of salicylic acid may be tried. My own opinion, however, is that electricity at this stage is of infinitely less value than rest and baths, and indeed is worse than useless when acute inflammation is present. In chronic conditions the counter-irritating effect of the vacuum electrode over the nerve is quite undoubted.

Motor.—Here we are on safer ground. A neuritis must be severe indeed if the muscles it supplies are beyond recovery. The same principles must be adopted as in the

treatment of gunshot wound of nerve; the limb is warmed and rested, and the muscles are tested if necessary for reaction of degeneration. If the condition is acute, no electrical treatment is admissible, resting and soothing measures only are adopted; in sub-acute and chronic conditions very gentle exercise of the individual muscles is given; if they react to interrupted current they are cautiously exercised with the Bristow battery, taking care not to over-fatigue or over-stimulate them; if they do not so react, they are made to contract with the interrupted galvanic current, using the anode or kathode according to which gives the better contraction. If no contractile response can be obtained it is useless to torment the inactive muscle with heavy currents, and counter-irritation of the nerve, ensurement of rest, and just sufficient gentle massage of the muscle to prevent adhesions and to promote circulation is all that can be done. The keynote of the treatment of neuritis, it will be observed, is *rest* rather than electricity.

Neuralgia.—Here, again, we may speak more confidently. Counter-irritation by the vacuum electrode or by sparking, faradic current, sinusoidal current, or anodal stroking may all afford relief. In obstinate cases the introduction of salicylic ions is often effectual, if the nerve is sufficiently superficial.

Sciatica may be a neuralgia, a neuritis, a perineuritis, or may be of central origin, and its treatment will obviously depend upon the diagnosis of the cause.

Trigeminal neuralgia can be treated by the vacuum electrode; other electric currents can hardly be used to the head in sufficient strength. Like all other neuralgias, it may be improved by general tonic measures, such as the negative breeze of the static machine; sometimes the sedative action of an electric bath succeeds, though it is doubtful what proportion of the credit should be given to the electricity and what to the bath.

Spasmodic Twitchings and Contractures.—Gentle electric currents give great relief in some cases, but their action

is uncertain, probably because the ætiology of the condition is as frequently uncertain.

Functional Diseases of the Nervous System.—Here we may meet with the greatest success, the treatment acting by suggestion. Close supervision, however, is needed, as by drawing attention to the part by treatment we may only succeed in riveting the affliction more firmly on the patient.

Organic Lesions of the Central Nervous System.—Treatment of the central nervous system by electricity is, I believe, quite useless,¹ but we can treat the *results* of the lesion.

Thus, in *hemiplegia* we can most usefully exercise the paralysed muscles pending the time that the central ganglia regain control, and by so doing we prevent a good deal of unnecessary muscular atrophy, and so shorten convalescence. In the same way we can treat muscles paralysed by spinal lesions, if there is any hope of returning central control. We can attempt to stimulate the central control; this makes us feel that we are doing something, and, by making the patient also feel that something is being done, may lift him out of the slough of despond.

Adhesions and Scar Tissue.—Cataphoresis with chlorine or iodine ions, coupled with baths and massage, will often give the most brilliant results in the most unpromising cases, but prolonged treatment is necessary owing to the small depth of tissue penetrated by the ions at each sitting² and to the danger of burns if too intensive treatment is attempted.

¹ This is, of course, merely an expression of personal opinion.

² The depth to which ions penetrate the tissues varies, of course, to a large extent with the strength and duration of the current, but as a general rule it is no more than from 1 mill. to 10 millimetres. It is probable that the ions of the heavy metals combine with the phosphoric ions of the tissues to form insoluble phosphates, and so pass out of the ionic state in the form of a precipitate in the tissues, and are then unable to penetrate deeper (Lewis Jones, Latham and English's *System of Treatment*).

Chronic Ulcers.—Unhealthy granulations may be cleared up, and healing promoted, by the introduction of zinc ions.

Pruritus.—Pruritus ani and pruritus vulvæ may yield to cataphoresis with zinc or cocaine, or both, when other measures fail. High frequency treatment is also useful.

Gout and Rheumatism.—Localized gouty and rheumatic conditions may occasionally be treated advantageously by the introduction of appropriate ions by cataphoresis.

Skin Diseases.—The treatment of skin diseases by X-rays and by electric-light baths has hitherto been little practised at Rotorua, though facilities for such treatment exist.

High Blood-pressure.—Numerous cases of high blood-pressure are sent to our spas, and notably to Rotorua, for treatment. In addition, so large a proportion of the other cases exhibit this symptom that it is desirable in spa practice to make an examination of the systolic pressure a routine matter.

In patients in whom there is no apparent renal lesion, the treatment on the high-frequency couch would certainly appear to assist in lowering the pressure. Such treatment is of course usually combined with other measures, such as attention to the diet and bowels, to habits such as the excessive use of tobacco, with the use of hypothermal baths, and with the internal administration of radium water. A plant for the manufacture of radio-active water is available at the Rotorua baths, the usual dose hitherto being 10,000 Maché units per diem.¹

Medical Gymnastics, Active and Passive Movements.—While theoretically the value of these exercises in the treatment and prevention of disease is fully acknowledged, practically their use by the profession, except at a spa, is extremely limited. For the most part they require, for their successful performance, either a trained and trustworthy operator or the medical attendant must carry them

¹ The tendency of late has been towards the progressive increase of dosage, so that the maximal dose of a few years ago has now become the minimal dose.

out himself, an operation requiring much patience, special experience, and a good deal more time than can generally be afforded. A special institution, such as Rotorua, with its own trained staff, can therefore more conveniently deal with these cases than the general practitioner, and there is in addition the advantage that douche and bath treatment can also simultaneously be carried out.

The value of exercise in the development of muscle is of course universally recognized, but the value of the accurate dosage of gradually increased resistance is apt to be overlooked, though this of course is the very essence of the familiar Schott movements.

Baths, massage, and the like measures flush the muscles with blood, promote the absorption of exudates, and cause a temporary increase of muscular bulk. Electrical stimulation, through the nerve if that be intact, or directly of the muscle if the nerve be damaged, exercises the muscle and prevents its atrophy, while the reinforcing effect of the electric current on exhausted muscle is well known. No agent, however, has so powerful an effect as voluntary muscular contraction,¹ especially against a progressive resistance.

The principal points aimed at are :

(1) The strengthening of selected muscles, the action of which will tend to correct deformity, as in spinal curvature, or the toning up some hypotonic function, as in certain forms of constipation and in cardiac weakness.

(2) The co-ordination and re-education of muscular movements, as in locomotor and spastic ataxia, and after gunshot wounds of the nervous system.

(3) The breaking down of adhesions after traumatism or disease.

(4) Secondary effects, on metabolism in general and on

¹ To enable the voluntary use of partly paralysed muscle in G.S.W. of nerve and at the same time to prevent the muscle stretching, the author used rubber bands, harnessed to active muscles, to duplicate the paralysed ones (*Mil. Phys. Orthopædics*, Herbert, 1918).

the circulatory and digestive systems in particular, as a result of educated respiration.

Light Baths.—The effects of light on the organism are due to :

(a) the actinic rays.

(b) the calorific rays.

The actinic rays reflexly increase metabolism by stimulating the exposed nerve-endings. Oxidation is increased, as is evidenced by an increased output of carbonic acid, and the sweat glands would appear to be stimulated to greater activity. Light may be used in the form of sun-baths, as the electric-light bath, or locally, as in Finsen's method. The latter is not in use in the New Zealand baths, but the direct action of sunlight is much used at such open-air baths as the Postmaster at Rotorua, and greatly enhances the effect of the mineral water. I have on many occasions seen benefit result from exposing the joints of rheumatoid patients to direct sunlight, and chronic ulcers will heal, and some skin diseases clear up, under the same influence. Both are-light baths, with predominant actinic rays, and incandescent-light baths, with mixed rays, may be obtained at Rotorua. The effect of the baths is to combine the stimulus of light rays with more or less *radiant-heat* rays as desired, and radiant heat warms the tissues in a manner totally different from the conducted heat of an ordinary bath. The body temperature may rapidly be raised 4° F. or even 5° F., and Kellogg states that there is a markedly increased blood-count, while there is generally a rapid onset of profuse sweating. The bath is usually followed by a cooling measure, and the head is kept cool throughout. It is indicated more especially in chronic purin poisoning and in obesity.

Blue light, in which the ultra-violet rays as well as those of longer wave-length of the visible spectrum are excluded, is said to have a sedative and anæsthetic effect. This treatment can be obtained at Rotorua.

Heat.—This agent is of course a principal factor in

ordinary thermal baths, and in vapour baths. It can also be used in the form of dry hot air, either locally or generally. The apparatus in use at Rotorua is heated by dull red-hot electric wires in the walls of a metallic box. By such an apparatus a joint or a whole limb can be surrounded by dry air at a temperature of from 300° to 500° F. The essential effect of this is to cause intense hyperæmia of the part, with all the consequent toxin-neutralizing flood of plasma and phagocytic reparative activity so graphically pictured by Bier. The resultant relief of pain and stiffness in a joint so treated is often very striking, and constitutes the local hot-air bath one of the most useful weapons at our disposal in combating, say, an obstinately stiff and painful knee. The possibility of these baths so raising the local temperature as to exercise a bactericidal action is discussed elsewhere (p. 241).

CHAPTER XVIII

DIET

IT is hardly necessary to insist on the importance of diet in spa treatment: the difficulty unfortunately arises that in most of the British health resorts, including those of New Zealand, it is exceedingly difficult for a patient to obtain a specified diet. Even when facilities for procuring it exist the patient is generally so surrounded with edible temptations that it is almost asking of him too much wholly to resist, and it is only in a special institution that dietetic treatment can be properly carried out. In former days, when every kind of rheumatic condition was attributed to uric acid, a special spa diet was thought essential, and was inflicted in routine fashion on almost all patients. Such a uniform diet is now held to be not only unnecessary, but in most cases positively harmful. Apart from the fact that different forms of arthritic disease demand different diets, the personal idiosyncrasy of the patient must be studied, and in no branch of therapeutics is it more true that we must treat the patient rather than the disease.

Broadly speaking, while it is necessary in many cases of true gout to restrict the diet, and especially articles of food rich in nucleins and extractives, in the great toxic group—that is, in the polyarthritic cases exhibiting the jaw-neck syndrome¹—it is usually advisable to order an abundant and generous diet, and to restrict it only in so far as the digestive capacity of the individual compels.

Diet in Toxic Cases.—These cases, all due to some form of

¹ Cf. page 138.

bacterial toxin, comprise the familiar but ill-defined rheumatoid arthritis ; toxic arthritis due to infection from teeth, tonsils, appendix, etc. ; gonorrhœal arthritis ; dysenteric arthritis ; and cases following the acute specific fevers such as measles, scarlet fever, and so forth. There are also many cases in which the nature of the toxæmia is ill-defined or unknown, but which conform to the general type.

In all this class¹ special diet is of comparatively little value. The question of uric acid does not enter, except in those cases in which a pre-existing gouty condition is complicated by a superimposed toxæmia. In these latter it may be necessary to take into account the necessities of the gouty element, but as a rule the toxic side predominates, and the strict diet of gout requires severe modification.

The essential feature of the diet should be the maintenance of the strength and general condition of the patient, so that a full nourishing diet is indicated, while at the same time the digestive apparatus is carefully looked after and especial care is taken to ensure free action of the bowels, kidneys, and skin.

Diet in Gout.—It is of course only in gout that the uric acid element enters, and it is only in gouty cases that a really strict diet need be enforced.

We may define gout as a chronic intoxication with the products of metabolism, and essentially of proteid metabolism, which is accompanied by, though not necessarily caused by, an increase of uric acid in the body.

It is probable that the disease is due to deficient excretion rather than to excessive uric acid formation, and the deficient excretion may be due to (1) damaged kidneys, or (2) the form in which the uric acid is presented to them.

The uric acid is partly endogenous, the product of the metabolism of the patient's own body, and partly exogenous, derived from ingested food. By diet we can of course

¹ Appendix and allied cases require removal of the cause rather than dieting.

modify the amount of exogenous uric acid, and this in two ways: we can cut down the total quantity of food, or we can modify the quality. As a rule, both methods are necessary.

1. *The Quantity*.—Here the personal equation is a largely determining factor. Plethoric sthenic patients nearly always require some restriction of the total amount of food they take. They should always get up from the table slightly hungry. This would, however, be an unsafe rule in asthenic cases, which, after all, constitute quite a large proportion of the whole. At the same time, any excess of food stagnating in the bowel should be swept out by purgative waters or other medicine.

2. *The Quality*.—The bulk of exogenous uric acid is derived from—

(a) The splitting up and oxidation of nucleins. Certain glandular substances, such as the thyroid and pancreas, and the flesh of very young animals yield abundant nucleo-proteins, which are split up by ferments into protein and nucleic acid. Nucleic acid is further broken down during digestion by a ferment (nuclease) into purin bases, which in turn are converted into uric acid.

(b) Certain proteid food substances, especially animal extracts which are already rich in these purin bases.

(c) Certain vegetables, especially legumes, also contain purin bodies.

(d) A certain small but irreducible amount is formed from the ordinary proteins of food, though in the main proteids, other than the purins and nucleo-proteids, increase the urea secretion only, and not the uric acid.

There are other food substances which, while not adding directly to the uric acid output, may be of indirect importance in regard to its excretion. These are:

(a) Tea, coffee, and cocoa, which contain the methyl-purins theine, caffein, and theobromine. The corresponding purin bases in the urine are paraxanthin derived from the theophyllin of tea, heteroxanthin from caffein, and methyl-

xanthin from theobromine. Thus tea, coffee, and cocoa raise the total purin excretion, but not that of uric acid.

It is possible, however, that the increased excretory work thus thrown on the kidneys may further embarrass their work of uric acid excretion.

(b) Fats and carbohydrates. These economize the consumption of proteid, or, in other words, if a larger quantity of them is ingested a smaller amount of proteid food becomes an excessive, and therefore, in gouty cases, a poisonous amount.

(c) Sodium chloride. There is at present considerable diversity of opinion as to the action of common salt in gout. It has been argued that excess of sodium chloride tends to promote the formation of insoluble sodium biurate. On the other hand, many mineral waters used in the treatment of gout contain sodium chloride as their main ingredient, and Weber¹ says that "the increased secretion of common salt by the kidneys favours the solubility of uric acid and facilitates its elimination in the urine."

(d) Alcohol and condiments. Universal clinical experience has limited the use of these substances in gout. There are asthenic cases, however, in which both are distinctly indicated.

(e) Fruits. Here, again, there is a hopeless diversity of opinion. There can be no doubt whatever that many gouty patients are always injuriously affected by fruit, but this certainly is not the case with all.

Confusion of terms has been to some extent responsible for a rather general prohibition of the use of "acid" fruits in gout, it being overlooked that the vegetable acids increase the alkalinity of the blood.

Fruits are rich in potassium salts, and this potassium appears to displace and replace the sodium radicle of salts.² The general tendency of fruits is to alkalinize the blood, to render it richer in potassium salts, and to act

¹ *Balneotherapy*.

² Bunge, quoted by Stewart, *Manual of Physiology*.

as a diuretic and laxative. In view of the possibility of uric acid being presented to the kidneys as a comparatively insoluble compound, this displacing action of potassium may have considerable value, a value enhanced by the simultaneous diuretic and laxative action.

Purin-free Diet.—A strictly purin-free diet is as a rule neither feasible nor desirable for continuous use in gouty patients taking a course of mineral-water treatment. Such a restricted diet would, especially in conjunction with baths, speedily lead to a dangerous debility. The list would comprise, among other things, eggs, milk, white bread, butter, biscuits, cereals, cream, sugar, syrup, jam, marmalade, cake, cream soups, potatoes, cauliflower, lettuce, nuts, cheese, ices, rice, cornflour, tapioca, custards, unfermented fruit juices. Its only use is either (*a*) to serve as a basis or guide in drawing up a diet sheet to which can be added such comparatively innocuous foods as may be thought advisable by the prescriber; or (*b*) as a temporary measure to clear the urine of exogenous uric acid as a preliminary step in estimating the patient's purin tolerance.

(*a*) Thus the diet of a gouty patient at a spa may consist of: (1) any or all of the above-mentioned purin-free articles, in so far as they agree with the patient's digestion; (2) foods of moderate purin content, e.g. fish, fowl, mutton, or a very little beef, but not young chicken, veal, or lamb, nearly all "above ground" vegetables, but with legumes strictly limited, and such fruits as agree.

Glandular substances, much beef, stock soups, the flesh of very young animals, and, generally, alcohol should be forbidden.

(*b*) To estimate his purin the patient is put on a strictly purin-free diet for five days.

The factor of the exogenous uric acid being thus eliminated, his endogenous excretion can be measured, and it can be observed whether he is excreting his normal quantity of uric acid, or whether too much is being locked up. He is now given a measured quantity of purin in the

form of food, and his output of uric acid is again measured daily.

Deducting the previously measured endogenous uric acid, his exogenous output is found. By Van Noorden's method, if less than a certain proportion of the purin intake is excreted as uric acid, we conclude that we have exceeded the patient's purin tolerance, and so repeat with half-doses. By Umber's method it is noted whether or how much the excretion of exogenous uric acid is delayed beyond the normal twenty-four hours. Thus, if the delay is three days, the patient is put on a purin-free diet, with purin food every three days.

Diet in Rheumatism.—As true rheumatism is a disease not of uric acid, but of bacterial origin, the diet is much as in the syndrome cases. As acute rheumatism is not a disease suitable for spa treatment, the question of diet does not concern us here. In convalescence after acute rheumatism we have to concentrate on maintaining the strength of the patient and combating the anæmia.

Chronic rheumatism is so indefinite a term that it is difficult to lay down any general rules as to diet.

If we eliminate all cases which are really of gouty origin, then we have to study the digestive capacity and idiosyncrasy of the patient, and to clear our minds entirely of any consideration of a problematical uric acid diathesis.

CHAPTER XIX

ENVIRONMENT—CLIMATE—SUGGESTION

Change of Environment.—This includes not only change of scene, but of climate, rest from ordinary occupation, amusements, and new interests. The beneficial effects of change, even apparently for the worse, in the convalescence from acute disease or during the slow course of chronic disease, are so much a part of universal human experience that there is no need to labour the point of proof. It would seem almost an instinct for humanity to sigh for fresh scenes and fresh faces at certain stages of convalescence—surroundings that shall have in them no link of association with the disagreeable time of illness. The patient confined to one room associates a pattern on the wallpaper, a certain blotch on the ceiling, a certain limited view from the window, for ever with disagreeable experiences. He is moved to another room, the thread of unpleasant memory is broken, there is a sense of fresh interest, of recuperation. To a less degree this sense of confinement and monotony also applies to towns, and even countries: the same country is only a larger room; a foreign spa, with a foreign tongue and foreign customs, even with foreign discomforts, breaks still more the links with the past. For this reason, for English patients, the English spas can never hope to cope on quite equal terms with the foreign ones. The picturesque Maori inhabitants and the weird thermal phenomena of the Rotorua district are assets of no mean value to a health resort.

Climate.—This may act beneficially in two ways: firstly and in a general way, as part of the change of environment,

and secondly in a specific manner, if a resort has been chosen deliberately with a view to a climate specially suited to the individual needs of the patient.

On account of the circumscribed area of the country, the New Zealand spas cannot of course compete in the matter of choice of climate with those of Europe, wide-flung over a continent: there is, however, a certain choice of bracing and sedative climates, and for Australian visitors there is the complete change from a continental to an island atmosphere. The climate of each individual resort is considered with the description of each spa: that of New Zealand as a whole is dealt with in a special chapter contributed by the Government Meteorologist.

Suggestion.—It has been frequently advanced, chiefly by those who have had no opportunity or curiosity to inquire into the subject, that suggestion alone is the curative agent in spa treatment. That suggestion plays a part, and a most important part, not only in the relief of indefinite and borderland cases, but in the treatment of definite disease, it would of course be preposterous to deny, and indeed there can be no doubt that the whole atmosphere of a mineral-water resort lends itself most admirably to the fostering of an influence of suggestion. Such a therapeutic agent is one for which we cannot be too devoutly thankful, and one which it would be the height of folly to disdain, and he is most successful who uses every legitimate weapon in his armamentarium as occasion may arise. Doubtless the spa physician finds his environment facilitates the use of suggestive treatment, but there is no medical man who does not consciously or unconsciously use suggestion every day of his life.

APPENDIX

TABLE OF MINERAL WATERS ARRANGED ACCORDING TO THEIR OSMOTIC PRESSURE

THE following table shows some of the principal mineral waters arranged according to their osmotic pressure, relative to that of the blood. It is only approximately accurate, a margin of 150 grains per gallon being allowed on either side of the isotonic point. Further, as we have already seen (page 233), in estimating the osmotic pressure of a water, we have to take into account the number of free ions in solution rather than the number of molecules, and, to arrive at this, the relative depression of the freezing-point of the solution as compared with that of pure water has to be noted. So far no cryoscopic examination of the New Zealand waters has been made, and the results here are therefore shown as molecular concentration relative to a solution of sodium chloride isotonic with blood (0.9 per cent. or 630 grains per gallon), and the possibilities of ionization are ignored.

The importance of the classification lies in the fact that each class has certain therapeutic characteristics.

Thus, *isotonic* solutions, taken internally, are more easily absorbed into the blood, and indeed are sometimes administered hypodermically or intravenously, e.g. the waters of La Bourboule, and, again, diluted sea-water.¹ Strong *hypertonic* waters are apt to prove irritating to the stomach, but may be given in small doses, when the kidneys are sound, to relieve hydræmia and abdominal plethora; nearly all purgative waters are hypertonic.

Hypotonic solutions tend to dissolve mucous deposits and bring about dilatation of the vessels.²

| HYPOTONIC | | HYPERTONIC | |
|--|--|--|---|
| All the "Sulphur Waters" except White Island, and including Rotorua, Taupo, Wairakei, Hammer, etc. All the "Simple Thermal Waters" | Motu Ngakawau Ngawha Ohaewai Ormond Valley Paeroa Papaiti Patangata Pipiriki Puketitiri Rahu Raukawa Soda Spring, Taupo Te Aroha: magnesia " chalybeate Waikohu Waikoura Wairongoa Waitangi Waitoa Waiwera | Parakao Puriri Te Aroha: hot alkaline Weber | Great Barrier Hokianga Kawhia Kopuowhara Kotuku Maranga Mataroa Mokau Morere Okain's Bay Pahaua Taumaranui Te Kuiti Te Puia Totoro Wallingford White Island |
| Abbotsford Akitio Bay of Islands Copland River Fox River Heathcote Valley Helensville Hikutaia Kamo Kati-kati Lyttelton McLean's: Napier Mahurangi Matamata Mercury Bay Miranda | ISOTONIC Ihuraia | | |

¹ Sea-water varies considerably in its saline content in different oceans: the Mediterranean and Atlantic average 3 to 4 per cent.

² Fortescue Fox: *Med. Hydrology*.

INDEX

A

Aachen, 71, 210
 Abbotsford spring, 190, 200
 A. C. Bath, Taupo, 195
 Access to spas, 11
 Accessory physical treatment, 257
 Acid baths, 77, 84, 255
 " " dangers of, 85
 " carbonic, gas baths, 77, 131
 " " " springs, 29
 " hydrochloric, 29, 198, 199
 " pentathionic, 199
 " sulphuric, 75, 197 et seq.
 " sulphurous, 21, 22, 29, 254
 " waters, 29, 75, 197
 " " origin of, 30
 Acidulated waters, 192
 Acne, 159
 Actinic rays, 266
 Active hyperæmia, 249
 Acute rheumatism, 140
 Adhesions, treatment of, 263
 Akitio spring, 190
 Alcohol, 271
 Alkaline waters, 28, 112, 178
 Alterative action of waters, 227
 Amberley springs, 191
 Anæmia, 84, 121, 133, 157, 178, 184, 186
 Anions, 232
 Antacids, 114, 178, 184
 Aorangi spring, 188
 Aratiatia Rapids, 105
 ARNOZAN and LAMARQUE: colloids, 234
 Arsenic spring, Taupo, 189
 " waters, 202
 Arthritis, 145, 159, 161
 Astringents, 184
 Auckland, climate of, 211

B

Bagnères de Luchon, 193
 BARR, SIR J., silicates in diet, 68

BARUCH, hyperæmia, 243, 251
 BATES, REV. D. C., climate, 211
 Baths, acid, 77, 84
 " alkaline, 68, 121
 " Berthollet, 85
 " cold, 248, 252
 " effervescing, 131, 155
 " electric, 73, 97, 260
 " hot, 249, 252
 " light, 266
 " mineral, 254
 " mud, 87
 " physical pressure of, 254
 " plain water, 236
 " Russian, 85
 " subthermal, 77, 132, 154
 " swimming, 73, 97
 " tepid, 251
 " vapour, 85
 Bath establishments, Hanmer, 96
 " " Helensville, 124
 " " Kamo, 131
 " " Morere, 128
 " " Okoroire, 134
 " " Rotorua, 62
 " " Tarawera, 125
 " " Taupo, 107
 " " Te Aroha, 121
 " " Te Puia, 129
 " " Tokaanu, 110
 " " Waingaro, 136
 " " Wairakei, 104
 " " Waiwera, 123
 Bay of Islands spring, 190
 BENEKE, sweating, 242
 BICKEL, sodium bicarbonate, 114
 BIER, hyperæmia, 251, 258
 Blood circulation, effect of baths on, 243
 Blood contents, effect of baths on, 80, 243
 Blue light, 266
 Boilers, the, 103, 109, 189, 200
 Boiling springs, evolution of, 35
 Borates, 28, 72, 95, 203

Borates, toxic action of, 95
 BROWN, D., pharmacological action
 of sulphur waters, 70
 BRUN, volcanic gases, 10
 Burton's spring, 203

C

Calcareous waters, 184
 Calcic-sodic-muriated waters, 171
 Calculus, biliary, renal, vesical, 117,
 157
 California springs, 114, 197
 Calorific rays, 266
 Cameron spring, 201, 202
 Carbonic acid gas baths, 77, 130, 251
 " " " indifferent tem-
 perature of, 255
 " " " springs, 29, 131
 " " " volcanic, 21
 Cataphoresis, 263
 Chalybeate waters, 118, 120, 130,
 186
 Champagne spring, 91, 92, 196
 Change of environment, 274
 Charteris Bay springs, 183
 Chilblains, 154
 Chlorosis, 157, 186
 Christchurch, climate of, 218
 Church Bay springs, 183
 Classification of rheumatic diseases,
 137
 Classification of waters, 162
 Climate, effects of, 274
 " of New Zealand, 4, 211
 Clothing, invalid, 8
 Coffee Pot spring, 201
 Cold baths, 248
 " drinks, 234
 " springs, Te Aroha, 120
 Colloidal colouring of water, 25
 " state, 233
 Constipation, 156
 Constituents of water, origin of, 26
 Contrexéville, 184
 Convalescence, 159
 Correlated areas, 245
 Critical temperature of water, 17
 Crow's nest geyser, 106, 195
 Cryoscopy, 233
 Cystitis, 184
 CZERNY, on silicates, 68

D

Devil's Eyeglass spring, 189
 Diabetes, 118, 155
 Diathermy, 238, 241
 Diet in disease, 268

Diet while taking chalybeate water,
 186
 " while taking sulphur water, 90
 Dissociated water, 17
 Diuretic action of waters, 132, 178,
 184, 186
 Dunedin, climate of, 219
 Dysenteric arthritis, 141, 161
 Dysmenorrhœa, 159
 Dyspepsia, 156

E

Eczema, 158
 Effects of baths, 247
 " " drinking water, 235
 Electrical conductivity, Rotorua
 waters, 76
 Electrical treatment, 259
 Elevation of spas, 7
 Environment, 274
 Excretion of toxins, 242
 EXNER, blood-vessels, 250
 Explosion craters, 23

F

Fairy spring, radio-activity of, 91
 FELIX, silicates, 67
 FENNER, lithium, 95
 FLACK, M., artificial pyrexia, 239
 FOX, FORTESCUE, freshness, 230
 " " intensive action,
 239, 246
 Fox River springs, 185, 191
 Franz Josef water, 167
 Freshness, quality of, 83, 121, 132,
 166, 230
 Friedrichshall, 182
 Fruit diet, 271
 Fumarole, 15, 18, 23, 35
 Functional nervous diseases, 263
 Furunculosis, 159

G

Gases in baths, 254
 " radio-active, 22, 90
 " volcanic, 21, 29
 Gastein, 166
 GAUTIER, A., endogenous water, 230
 GEIKIE, superheated water, 27
 Geysers, 33 et seq.
 Glycosuria, 118, 155, 178
 Goitre, 176
 Gold in mineral mud, 202
 Gonococcus, effect of heat on, 241
 Gonorrhœal arthritis, 141, 161

Gout, 140, 145
 „ electrical treatment of, 264
 Great Barrier Island springs, 174
 Gymnastics, medical, 264

II

HAMMILL, borates, 204
 Hamurana, radio-activity of, 91, 92
 Hanmer springs, 93, 195, 205
 Harrogate, 193
 Haupiri, 167
 Hawke's Bay, climate of, 213
 HEAD, skin areas, 245
 Heart disease, 133, 155
 Heat, dry, 266
 Heathcote springs, 183
 HECTOR, SIR J., analyses, 164
 Helensville springs, 124, 170
 Hemiplegia, 154
 Hermitage, the, 7
 High blood-pressure, 155, 264
 Hikutaia spring, 205
 Hill climbing, 98
 HILL, L., artificial pyrexia, 239
 HILTON, nerve areas, 246
 Hokianga springs, 170
 Hokitika climate, 217
 Horakikumuru springs, 198
 Hormone action of CO₂, 259
 Hospitals (mineral water), 60, 100
 Hot drinks, 235
 Huka Falls, 105
 HUTCHINSON and COLLIER, lithium, 95
 HUTCHINSON, WOODS, skin-heart, 250
 Hydrochloric acid, 29, 198
 Hydrothermal phenomena, 15
 Hyperacidity, 115, 178
 Hyperæmia, 249
 Hyperpnœa, 239
 Hyperpyrexia, 238
 Hyperthyroid arthritis, 139
 Hypoacidity, 115, 178
 Hysteria, 152

I

Ihuraua spring, 177, 186, 189
 Indifferent temperature of gases, 248
 „ „ of skin, 248
 „ „ of water, 248
 Insomnia, 153
 Intensive action of baths, 239, 246
 Invercargill, climate of, 220
 Iodine, action of, 176

Iodine spring, Rotomahana, 189, 191
 „ waters, 126, 175
 Ionization, 231
 „ complete, 76
 Ions, depth of penetration, 263
 Iron spring, Taupo, 188
 IRVING, sulphur and mercury, 71

J

JANSSEN, spectroscopical examination of gases, 21
 Jaw-neck syndrome, 137, 138, 161
 JONES, L., acne, 159; ions, 263

K

Kamo springs, 130, 181
 Kaolin, 47
 Katikati springs, 168, 171
 Kations, 232
 Kauri gum, 210
 Kawhia springs, 173
 KELLOGG, massage, 258
 Kerapiti blowhole, 105
 Kiriohinekei spring, 103
 KISCH, on H₂S, 69; sodium bicarbonate, 115; iodine, 176
 KNOEFFELMACHER, blood, 244
 Kopuowhara spring, 174, 177
 Krakatoa obsidian, 16
 Kreuznach, 172
 Kuirau springs, 194

L

La Bourboule, 203
 Lake Sumner springs, 167
 Lakes, explosion crater, 23
 LANE, SIR A., arthritis, 143
 Laughing-gas spring, 201
 LEDUC, electrolysis, 95; ionization, 232, 233
 Lencorrhœa, 159
 Levico, 192
 Light baths, 266
 „ blue, 266
 LINossier, sodium bicarbonate, 114
 Lithium, 72, 95, 119, 173
 LLEWELLYN, arthritis, 139
 Lobster bath, 64
 Locomotor ataxia, 154
 Longitudinal fibres of arteries, 250
 Low blood-pressure, 155
 Lowering effect of waters, 116, 178
 LUFF, lithium, 95
 Lumbago, 150

M

- MACKENZIE, sensory areas, 245
 MACLAURIN, radio-activity, 90, 114
 „ analyses waters, 163, 199
 McLean's spring, 171
 McNEILL, borates, 204
 Magma, 16, 17
 Magnesia spring, Taupo, 205
 Magnesium waters, 119, 180
 MAGRANTI, blood, 243
 Mahurangi springs, 171
 Malfroy geyser, radio-activity of, 91
 Mangapakeha spring, 188
 Manupirua spring, 196
 Maranga springs, 177
 Marcasite, 31
 Maruia springs, 167
 Massage, 258
 Matamata spring, 135, 167
 Mataroa spring, 177
 Matuatonga spring, 195
 MELTZER, artificial pyrexia, 240
 Menorrhagia, 159
 Mercury Bay spring, 171, 175
 „ in mud, 209, 210
 Metabolism, effects of baths, 245
 Mineral-water treatment, 229
 Miranda springs, 168, 205
 Mokau springs, 171
 MOORE, B., renal calculi, 117
 Morere springs, 126, 174, 176
 Morinsville springs, 168
 Motu springs, 179, 190
 Mt. Cook, 7
 Mt. Egmont accommodation, 7
 „ „ springs, 167
 Mud, analyses, 88, 202, 209
 „ mercurial, 209
 „ radio-active, 91
 „ siliceous sulphur, 209
 „ springs, 47, 208
 „ volcanoes, 47
 Muriated waters, 168
 „ alkaline waters, 179

N

- Neilson's spring, 190
 Nelson, climate of, 216
 Nephritis, 157
 Nervous functional disorders, 152
 „ organic disorders, 153, 263
 Neuralgia, 152, 262
 Neurasthenia, 152
 Neuritis, 150, 261
 Ngauapua spring, S
 Ngawha spring, 187

O

- Obsidian, 16
 Ocean routes, 7
 Ohaewai spring, 180, 190, 200, 209
 Oil Bath, 194
 Okain's Bay springs, 173, 183, 188
 Okoroire springs, 134, 166
 Old Priest bath, 77
 Old Sulphur spring, Taupo, 195
 Onepu springs, 13, 196
 Onetapu springs, 191
 Organic nervous disorders, 153, 263
 „ origin of sinters, 46
 Origin of thermal waters, 16, 25, 30
 Original water theory, 17
 Ormond Valley springs, 182, 185
 Osmotic pressure, 233, 276
 Osteo-arthritis, 142
 Otway's spring, 179
 Oxaluria, 184

P

- Paeroa spring, 119, 188
 Pahana spring, 174, 177
 Painkiller spring, 64
 Papaiti spring, 170
 Parakao spring, 186
 PASCAULT, silicates, 68
 Patangata spring, 188
 PAWLOW, sodium bicarbonate, 114
 PEALE, classification of waters, 164
 Pelvic diseases, 159
 Pentathionic acid, 199
 Physical treatment, 257
 Pipiriki springs, 170
 PIPPING, pyrexia, 240
 Plain water, effects of, 234
 Plombières douche, 192
 POND, analysis of waters, 164
 Postmaster bath, 76, 79, 190, 197
 „ „ radio-activity, 91
 POYNTON, hyperthyroidism, 139
 Precautions in baths, 85
 Priest bath, 76 et seq., 197
 „ „ indications for, 84
 „ „ radio-activity of, 91
 Pruritus, 264
 Psoriasis, 159
 Puketitiri springs, 168, 205
 Pumice, formation of, 16, 20
 Puriri springs, 179

Q

- Queenstown, climate of, 7, 220
 QUISERNE, freshness of water, 231

R

- Rachel spring, 66, 189, 193
 " " radio-activity, 91
 Radio-activity, effects on ionization
 and on colloids,
 233
 " of gases, 90
 " of Hanmer waters,
 98
 " of mud, 91
 " of sinters, 92
 " of sulphur waters,
 91
 " of Te Aroha waters,
 114
 Rahu springs, 168, 187
 Raukawa springs, 170, 182
 RAWLINS, M., mercury, 71
 Raynaud's disease, 154
 Reaction of degeneration, 262
 " to baths, 248
 Red coral geyser, 196
 Renal calculi, 117, 157
 Rheumatic diseases, classification
 of, 137
 Rheumatism, 140, 148, 149
 " electrical treatment
 of, 264
 Rheumatoid arthritis, 140, 161
 Rhythmic contraction of blood-
 vessels, 250
 RITTER, blood, 251
 Roadman's bath, 167
 ROLLY, artificial pyrexia, 240
 Ross, correlated areas, 245
 Rotoitipaku spring, 196
 Rotokakahi spring, 171
 Rotorua, 54 et seq.
 " acid waters, 75
 " alkaline waters, 65
 " climate, 55, 212
 Routes, ocean, 7
 ROVIGHI, blood-count, 243
 Royat, 180
 Russian baths, 85

S

- SAINTE-CLAIRE DEVILLE, volcanic
 emanation, 29
 Salts in baths, effect of, 255
 Sanatorium, Government, 60, 100
 Saratoga springs, 114
 Scar tissue, treatment of, 263
 SCHEFFER, silicates, 68
 Schnee bath, 259, 261
 Sciatica, 150
 Scotch douche, 245
 Southland, rainfall of, 221

- Scrofula, 176
 SENG, G., borates, 204
 Senility, treatment of, 161
 Selective action of douches, 245
 Silica, 44
 " action of algæ on, 47
 Silicates, 26
 " action of, 67
 " toxic action of, 69
 Siliceous waters, 191
 Silver in mud, 202
 Simple thermal waters, 134, 164
 Sinter, 44
 " radio-activity of, 92
 Skin as an organ, 236
 " " heat regulator, 236
 " indifferent temperature of,
 248
 Skin-heart, 79, 161, 250, 255
 Soda spring, Taupo, 188
 Sodid muriated waters, 168
 Sodium bicarbonate, action of, 114
 " bicarbonate in waters, 112,
 178
 " borate, 28, 72, 95, 203
 " chloride action of, 116
 " " in diet, 271
 " " in lavas, 28
 " " in waters, 168
 " silicate, 67
 " sulphide, 69
 Solfataras, 21
 "Sources savonneuses," 192
 South Bay spring, 195
 Spa, 187
 " Taupo, 107
 " treatment, 225
 Spas, 52
 " choice of, 144
 Spasmodic contractions, 262
 Specific fevers and arthritis, 142
 Spinal paralyses, 154
 Spout baths, 64, 194
 " " radio-activity of, 91
 Steam, superheated, 35
 Stewart Island climate, 221
 STEWART, referred pain, 240
 STRASSER, blood-count, 243
 Suggestion, 275
 Sulphur, action of, 70
 " formation of, 22
 " in lead poisoning, 71
 " in mercury poisoning, 71
 " toxic effects of, 72
 " waters, 191
 Sulphur Point Spring, 197, 202
 Sulphuretted hydrogen in baths,
 effects of, 69, 255

Sulphuretted hydrogen in volcanoes, 21
 Sulphuretted hydrogen in waters, 60, also vide Sulphur waters
 Sulphuric acid, 75, 198
 Sulphurous acid, 21, 29, 254
 Sweat glands, effect of baths on, 242
 Syphilis, 71, 157, 176

T

Table waters, 206
 Taheke springs, 167, 198
 Tapapa springs, 179
 Taranaki climate, 215
 Tarawera mountain, 12, 23
 „ springs, 125
 Taumaranui springs, 175
 Taupiri springs, 187
 Taupo springs, 105, 200
 Te Aroha, radio-activity of waters, 91, 114
 Te Aroha springs, 111, 179, 181, 185, 187
 Te Koutu springs, 194
 Te Kuiti springs, 173, 177, 205
 Temperature of baths, effects of, 247
 „ of body, effects of baths on, 237
 Tepid baths, 251
 Te Puia springs, 128, 174, 176
 Terrace formation, 45
 Terraces, Taupo, 107, 196
 Te Teko springs, 167
 Thermal district, 11
 Tokaanu springs, 110
 Tonicity table, 276
 Top spring, terraces, 195
 Totoro, 174
 Toxins, excretion of, 242
 Traumatic arthritis, 142
 Traumatism, 159
 Tubercular arthritis, 142
 Twins geyser, 104

U

Ulcers, chronic, 264
 Unupokapoka spring, 196
 Uric acid, 242, 269

V

Vapour baths, 85
 Vasomotor disturbances, 154
 Vegetables in diet, 271
 Vesical calculus, 117, 157
 Vichy, 179

Virgin waters, 18
 Volcanic waters, 25
 Volcanoes, formation of, 16, 21
 „ gases from, 21, 29
 „ mud, 47

W

Waiariki spring, 195
 Waihumuhunukiri spring, 194
 Waikite, Ohinemutu spring, 194
 Waikohu spring, 183, 189
 Waikoura spring, 185, 187
 Waikupapapa spring, 198
 Waingaro, 136, 166
 Waiotapu, 101, 167, 196
 Wairakei, 103, 196, 200
 Wairakei geyser, radio-act. of, 91
 Waitangi spring, radio-act. of, 91
 Waiwera, 123
 Warm drinks, 235
 Waters, acid, 29, 75, 197
 „ acidulated, 192
 „ alkaline, 28, 111, 178
 „ „ muriated, 124, 179
 „ „ sulphur, 65, 192
 „ arsenical, 199, 202
 „ borated, 94, 203
 „ calcareous, 118, 120, 130, 184, 187
 „ calcic-sodic-muriated, 126, 128, 171
 „ chalybeate, 118, 120, 130, 186
 „ iodine, 126, 175
 „ magnesium, 118, 180
 „ muddy, 201
 „ muriated, 123, 168
 „ siliceous, 54, 191
 „ simple, 134, 164
 „ sulphur, 54, 191
 „ table, 206
 Waters (springs):
 „ Aachen, 71, 210
 „ Abbotsford, 190, 200
 „ A. C. bath, Taupo, 195
 „ Akitio, 190
 „ Amberley, 191
 „ Aorangi, 188
 „ Arsenic spring, Taupo, 189
 „ Bagnères-de-Luchon, 193
 „ Bay of Islands, 190
 „ Boilers, 103, 100, 189, 200
 „ Borate springs, California, 205
 „ Burton's, 203
 „ Cameron, 202
 „ Champagne, Waiotapu, 91
 92

Waters (springs)—*continued* :

- .. Champagne, Wairakei, 196
- .. Charteris Bay, 182
- .. Church Bay, 182
- .. Coffee Pot, 201
- .. Contrexéville, 184
- .. Copland River, 185, 190
- .. Crow's Nest, 104, 195
- .. Devil's Eyeglass, 189, 200
- .. Fox River, 185, 190
- .. Franz Joseph, 167
- .. Friedrichshall, 181
- .. Gastein, 166
- .. Great Barrier, 174
- .. Hammer, **94**, 195, 205
- .. Harrogate, 193
- .. Haupiri, 167
- .. Heathcote, 183
- .. Helensville, **125**, 170
- .. Hikutaia, 205
- .. Hokianga, 170
- .. Horakikimururu, 198
- .. Ihuraua, 177, 186, 189
- .. Iodine, Rotomahana, 180, 196
- .. Iron, Taupo, 188
- .. Kamo, **130**, 181, 185, 187
- .. Katikati, 168, 171
- .. Kawhia, 173, 176
- .. Kopuowhara, 174, 177
- .. Kotuku, 174, 188
- .. Kreuznach, 171
- .. Kuirau, 194
- .. La Bourboule, 203
- .. Lake Sumner, 167
- .. McLean's, 171
- .. Magnesia, Taupo, 205
- .. Mahurangi, 171
- .. Manupirua, 196
- .. Maranga, 177
- .. Maruia, 167
- .. Matamata, **135**, 167, 182
- .. Mataroa, 173, 177
- .. Matuatonga, 195
- .. Maungapakcha, 188
- .. Mercury Bay, 171, 175
- .. Miranda, 168, 205
- .. Mokau, 171
- .. Morere, **126**, 174, 176
- .. Morinsville, 168
- .. Motu, 179, 190
- .. Mt. Egmont, 167
- .. Ngakawau, 173
- .. Ngaruapua, 198
- .. Ngawha, 187
- .. Neilson's, 190
- .. Ohaewai, 180, 189, 200, **210**
- .. Oil Bath, 194

Waters (springs).—*continued* :

- .. Okain's Bav, 173, **183**, 188
- .. Okoroire, **134**, 166
- .. Onepu, 13, 196
- .. Onetapu, 191
- .. Ormond Valley, 182, 185
- .. Otway's, 179
- .. Paeroa, 119, 188
- .. Pahaua, 174, 177
- .. Papaiti, 170
- .. Parakao, 186
- .. Patangata, 188
- .. Pipiriki, 170
- .. Postmaster, **76**, 79, 190, 197
- .. Priest, **76**, 197
- .. Puketitiri, 168, 205
- .. Puriri, 170
- .. Rachel, **66**, 189, 193
- .. Rahu, 168, 187
- .. Raukawa, 170, 182
- .. Red Coral Geyser, 196
- .. Rotoitipaku, 196
- .. Rotokakahi, 171
- .. Rotorua, **65** et seq., 189, 193 et seq.
- .. Royat, 180
- .. Selters, 207
- .. Soda, Taupo, 188
- .. South Bay, Taupo, 195
- .. Spa, 187
- .. Spout Bath, 194
- .. Sulphur Point, 197, 202
- .. " Terrace, 200
- .. Taheke, 167, 198
- .. Tapapa, 179
- .. Taumaranui, 175
- .. Taupiri, 187
- .. Taupo, **105**, 109, 195, 196, 200
- .. Te Aroha, **111**, 179, 181, 185, 187
- .. Te Koutu, 194
- .. Te Kuiti, 173, 177, 205
- .. Te Puia, **128**, 174, 176
- .. Te Teko, 167
- .. Terraces, Taupo, 196
- .. Top spring, Terraces, 195
- .. Totoro, 174
- .. Umupokapoka, 196
- .. Vichy, 179
- .. Waiariki, 195
- .. Waihunuhunukuri, 194
- .. Waikite, 194
- .. Waikohu, 183, 180
- .. Waikoura, 185, 187
- .. Waikupapapa, 198
- .. Waingarō, **136**, 166
- .. Waiotapu, **101**, 167

Waters (springs) — *continued* :

- Wairakei, **103**, **109**, 200
- Wairongoa, 181, 185, **207**
- Waitangi, 187
- Waitoa, 179
- Waiwera, **123**, 180, 188
- Wallingford, 175
- Wanganui River, 168, 170
- Webb's, 177
- Weber, 177
- Whale Island, 190, 190
- Whangape, 167
- White Island, 190, **139**,
203, 205
- Wiesbaden, 170
- Woodhall, 170

- Wellington, climate of, 214
- Westland, climate of, 216
- WINTERNITZ, blood-content, 243
- Withdrawal of liquid from body,
241

Y

- Young animals, effects of silicates
on, 27
- “ “ nucleo-proteins in
flesh of, 270

Z

- ZELLER, silicates in cancer, 68
- ZIKGRAF, silicates in tuberculosis, 67





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